Take it to the MAX: Optimizing Closed-Circuit Reverse Osmosis for Brine Recovery in Brackish Groundwater Treatment

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- DuPont (Desalitech)
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emwd

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Acknowledgements

- United States Bureau of Reclamation
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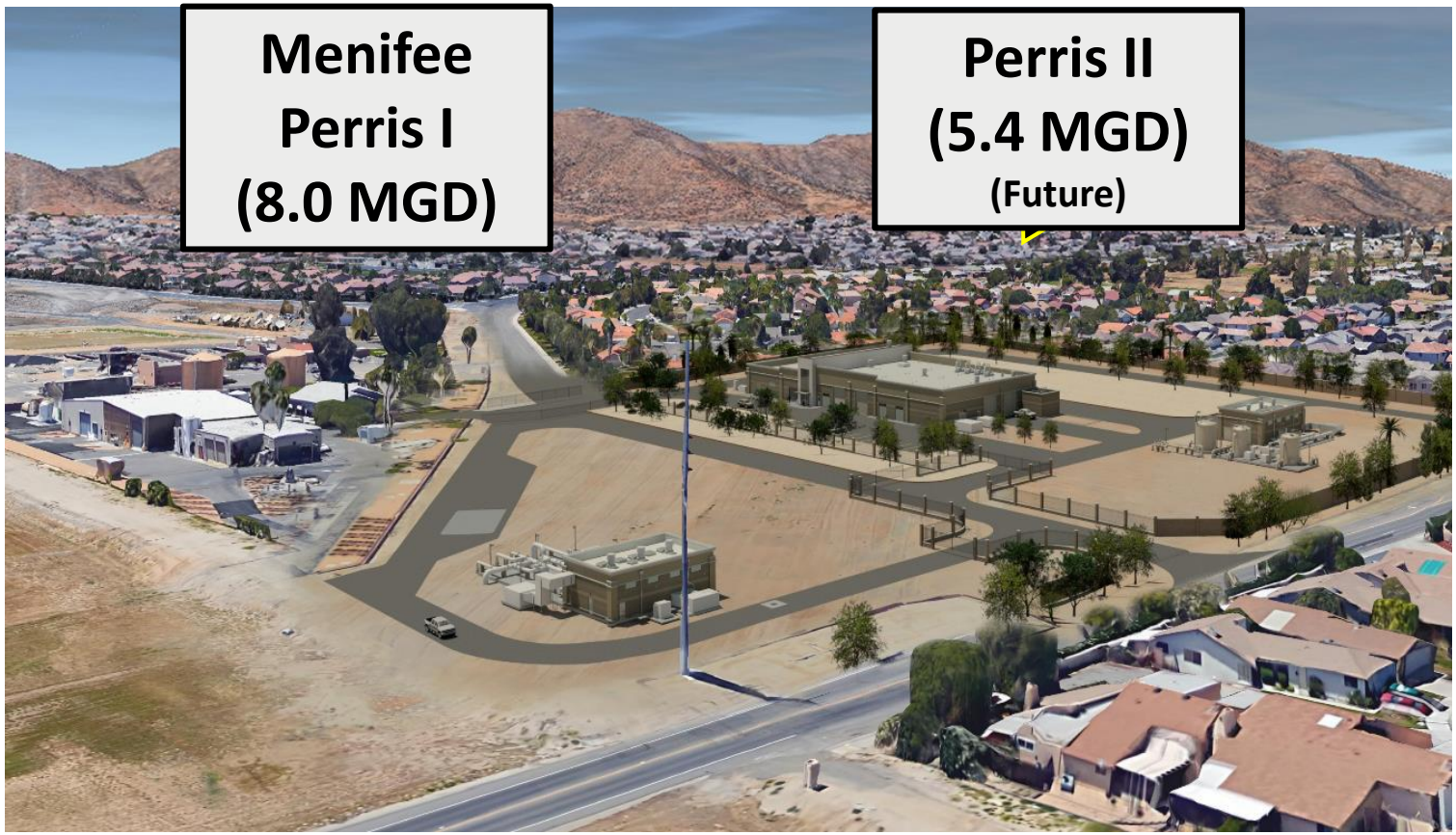
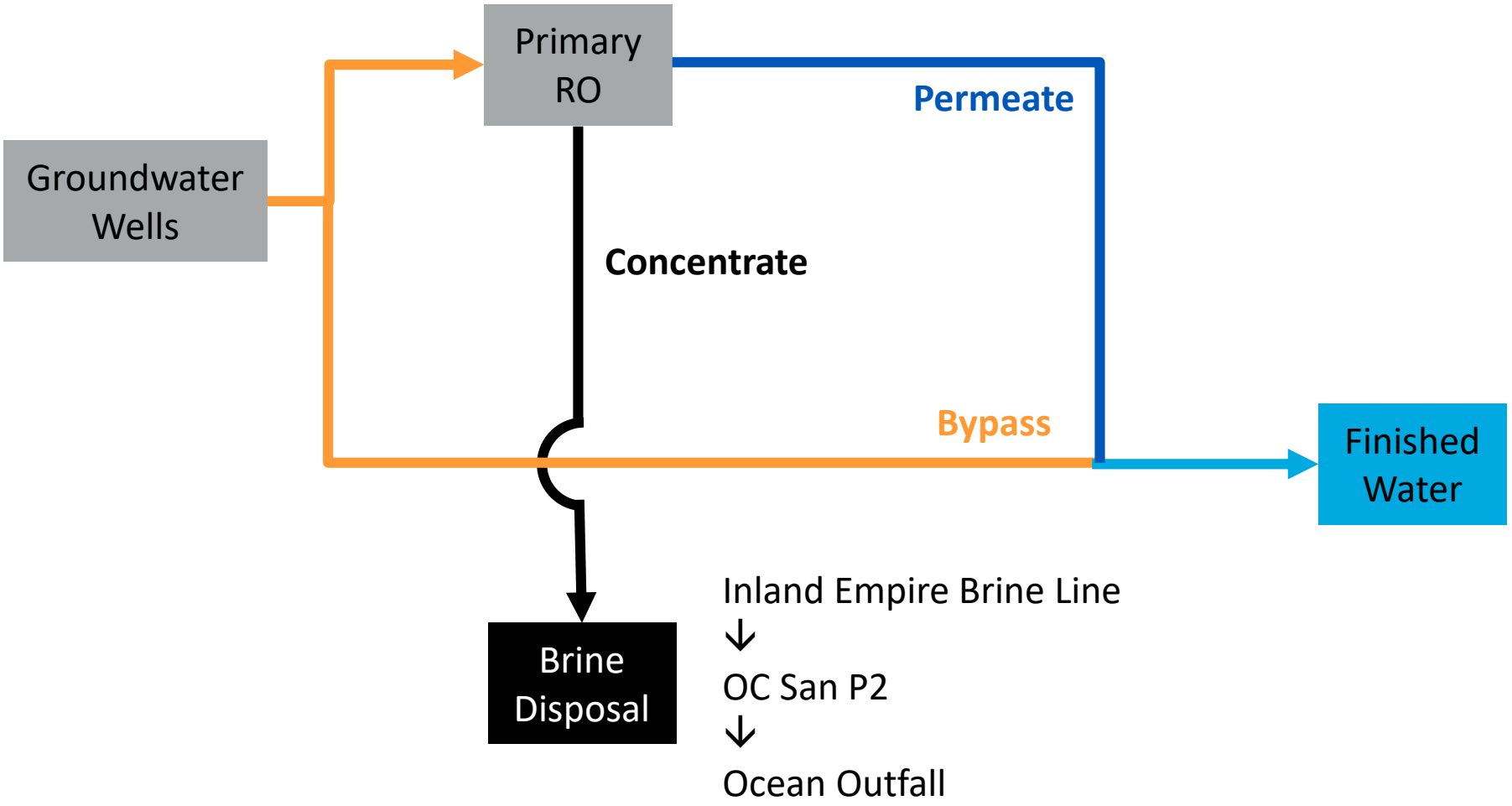
- California Department of Water Resources
  - Proposition 1 Water Desalination Grant Program

Background

EMWD Desalination Complex



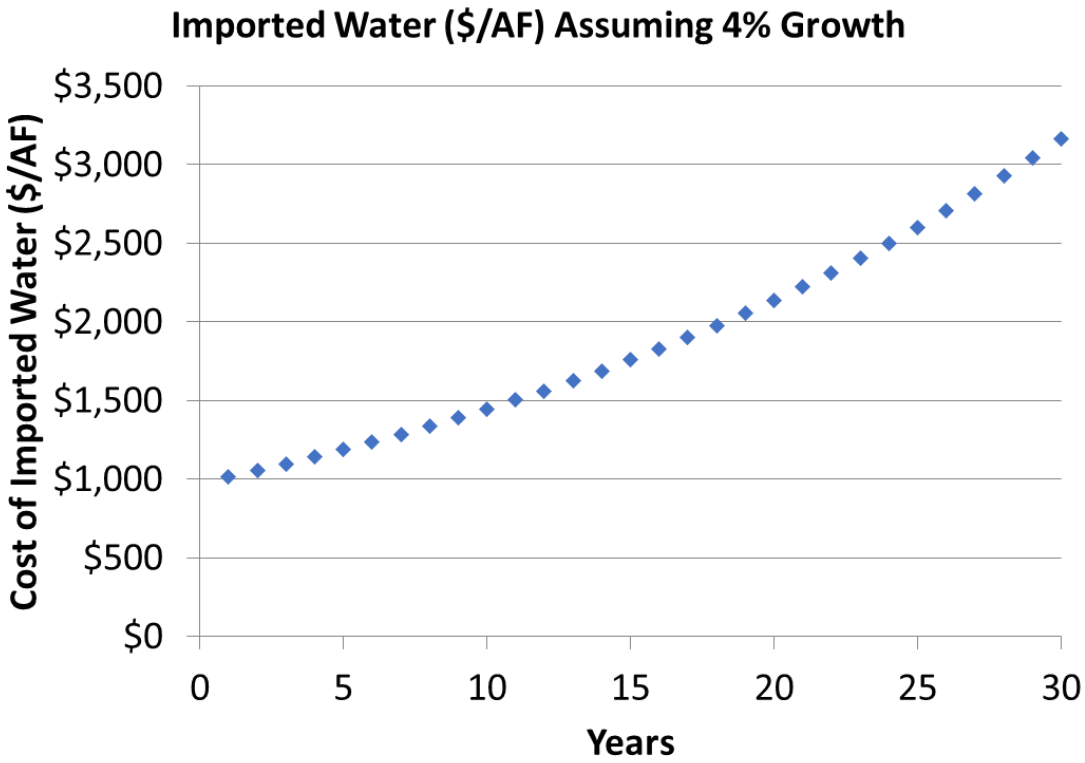
Process Flow



Why Test High Recovery?

PERMEATE

BRINE



Strategic Priorities

Water Supply Diversity and Reliability

Water Quality Management

Groundwater – High Scaling Potential

$CaCO_3$

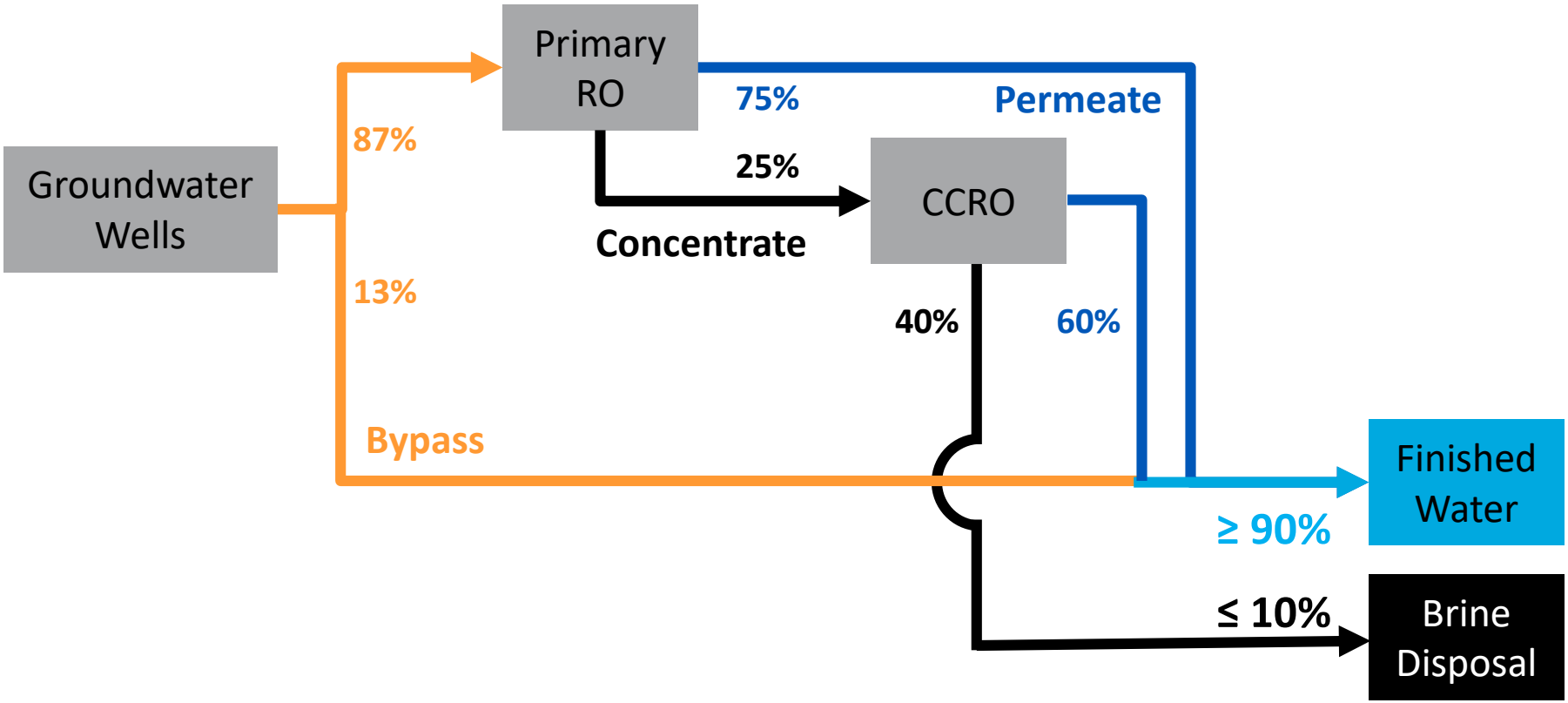
Calcium Carbonate

Si

Silica

Goals and Objectives

Total Water Recovery Goal: ≥90%



Objectives

- Evaluate Desalitech (DuPont) Closed-Circuit Reverse Osmosis (CCRO) as a high-recovery treatment system

- Maximize value-per-unit of recovered water

Testing Phases

PHASE 1

- ❑ 2018 – 2019
- ❑ CCRO ReFlex™
- ❑ Primary and Brine Recovery

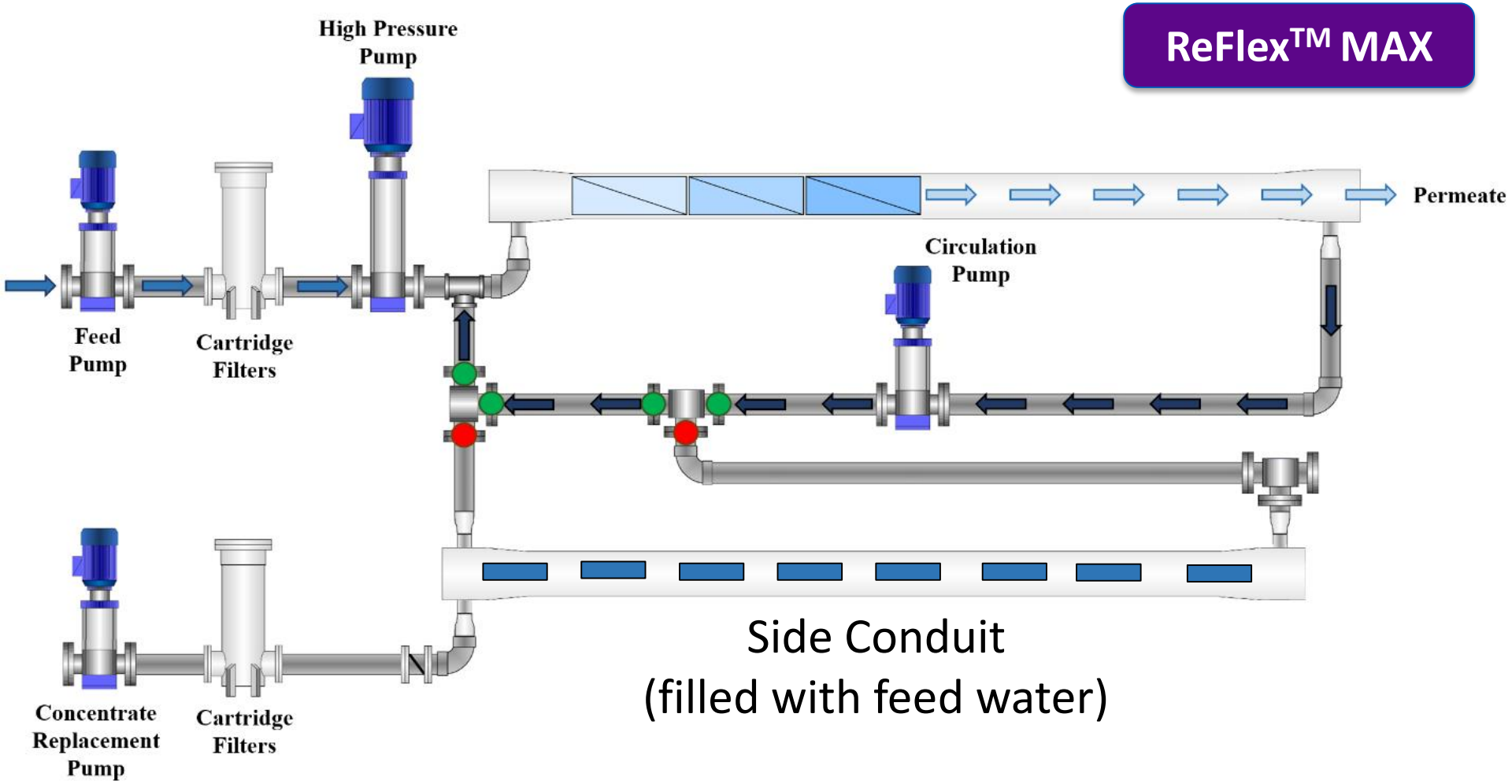
PHASE 2

- ❑ March 2021 – Present
- ❑ CCRO ReFlex™ MAX
- ❑ Brine Recovery only

CCRO Technology

Image credit: Desalitech (DuPont)

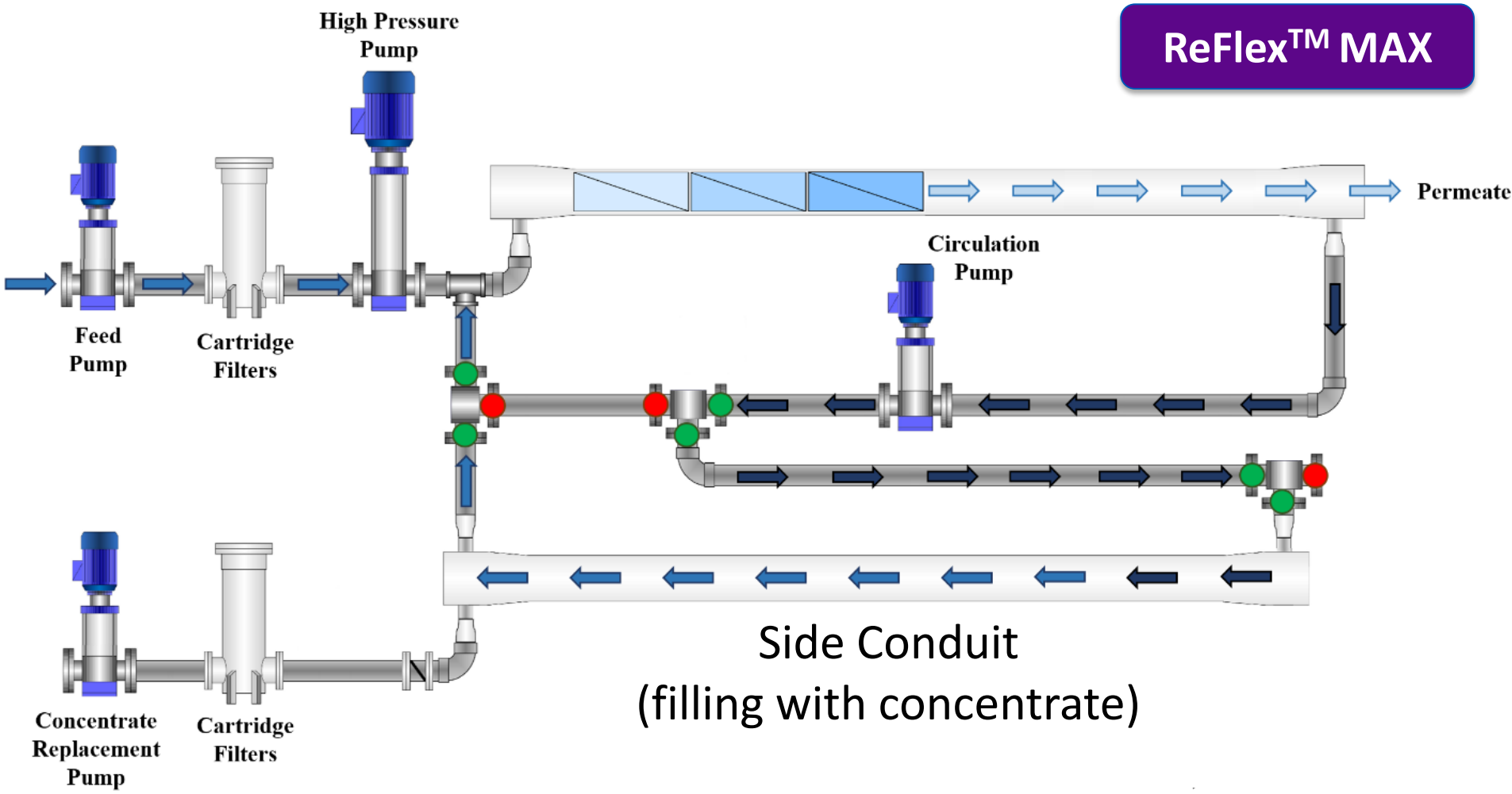
ReFlex™ MAX



Side Conduit
(filled with feed water)

Image credit: Desalitech (DuPont)

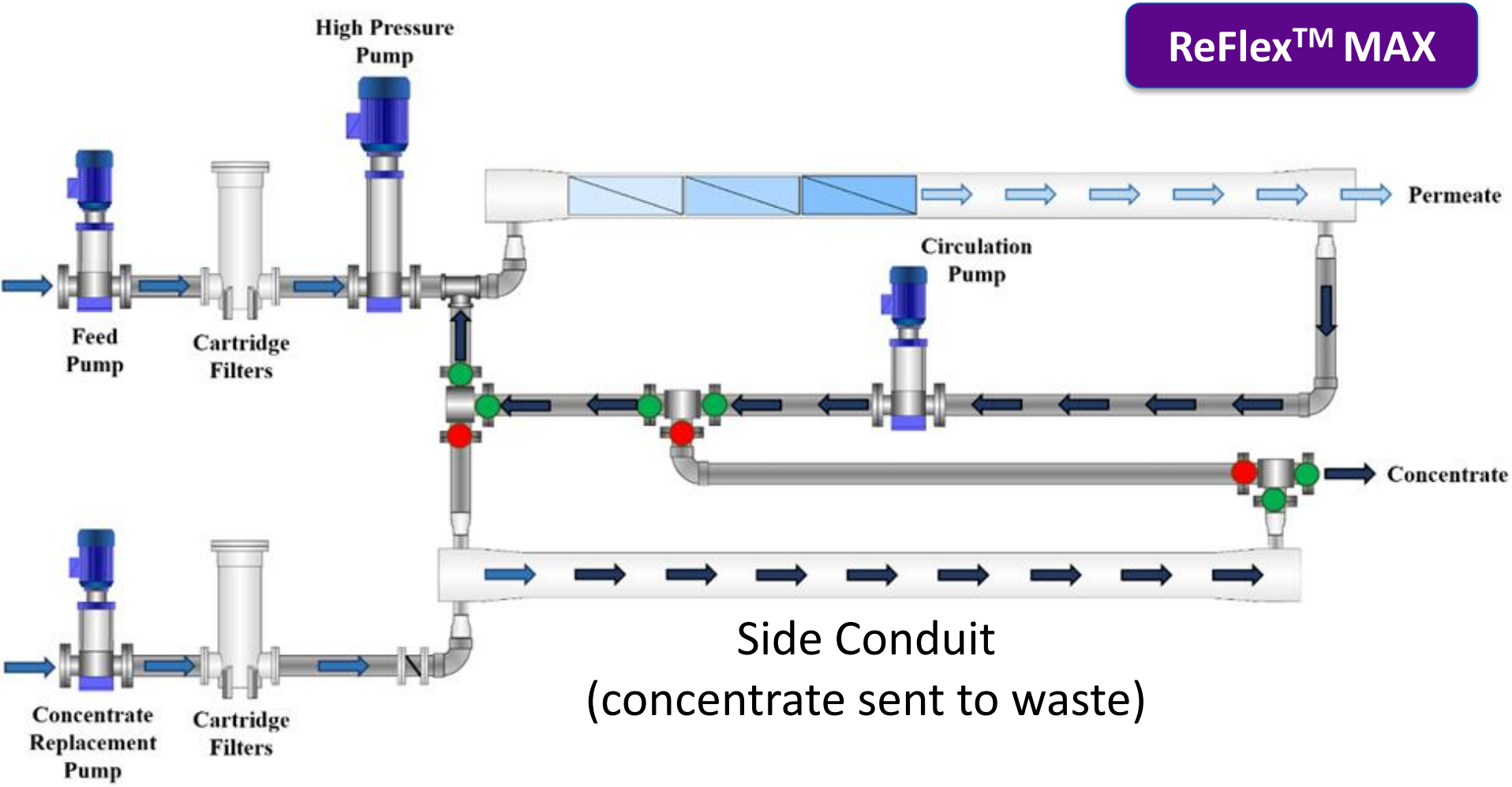
ReFlex™ MAX



Side Conduit
(filling with concentrate)

Image credit: Desalitech (DuPont)

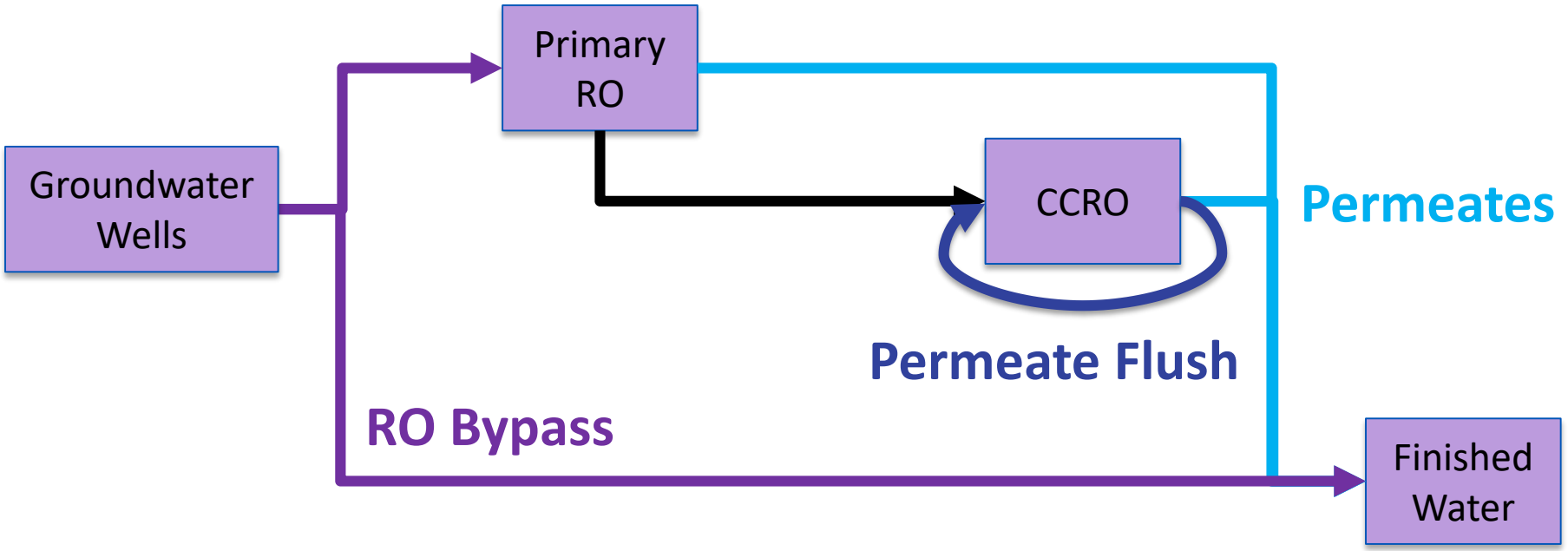
ReFlex™ MAX



Side Conduit
(concentrate sent to waste)

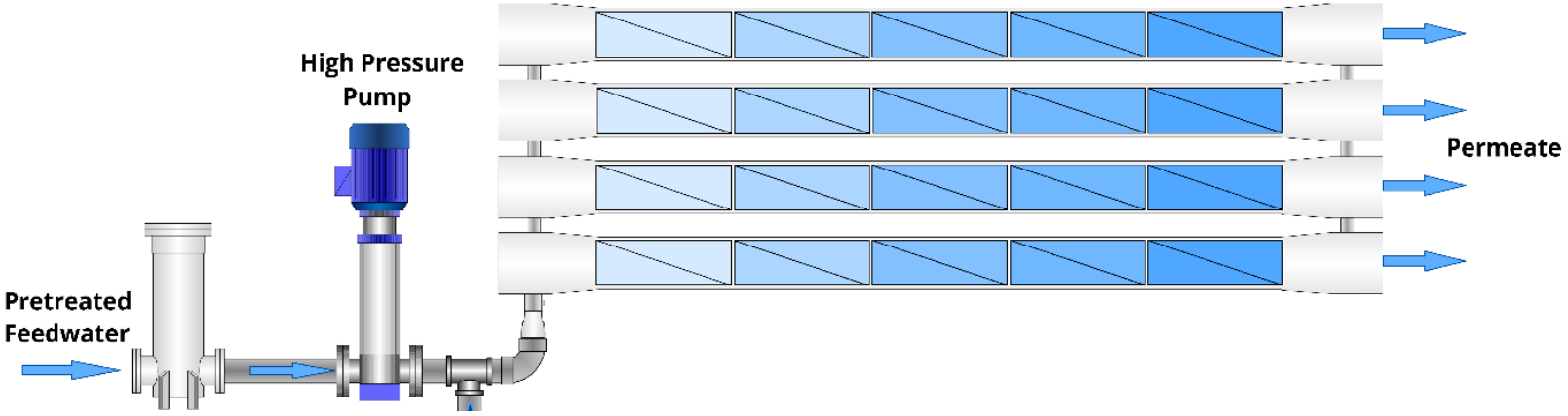
Definitions

TOTAL WATER RECOVERY (Goal = 90%)



"Total Water Recovery" = $\frac{\text{Permeates} + \text{RO Bypass} - \text{Permeate Flushes}}{\text{Groundwater Feed}}$

NORMALIZED PERMEABILITY = $\frac{\text{Permeate (gfd)}}{\text{Net Driving Pressure (psi)}}$



High Permeability = **Low** fouling or scaling

Low Permeability = **High** fouling or scaling

Phase 1 Results

Testing Phases

PHASE 1

- ❑ 2018 – 2019
- ❑ CCRO ReFlex™
- ❑ Primary and Brine Recovery

PHASE 2

- ❑ March 2021 – Present
- ❑ CCRO ReFlex™ MAX
- ❑ Brine Recovery only

TEST 1 = Brine Recovery Utilizes Existing Infrastructure

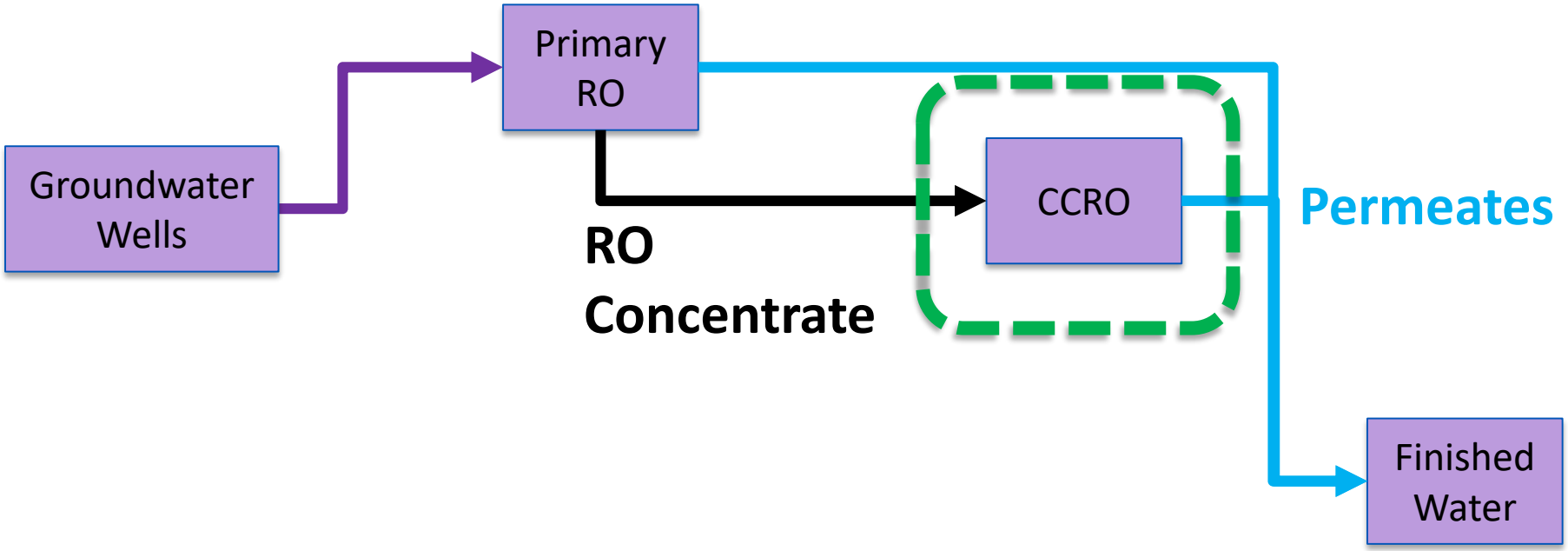
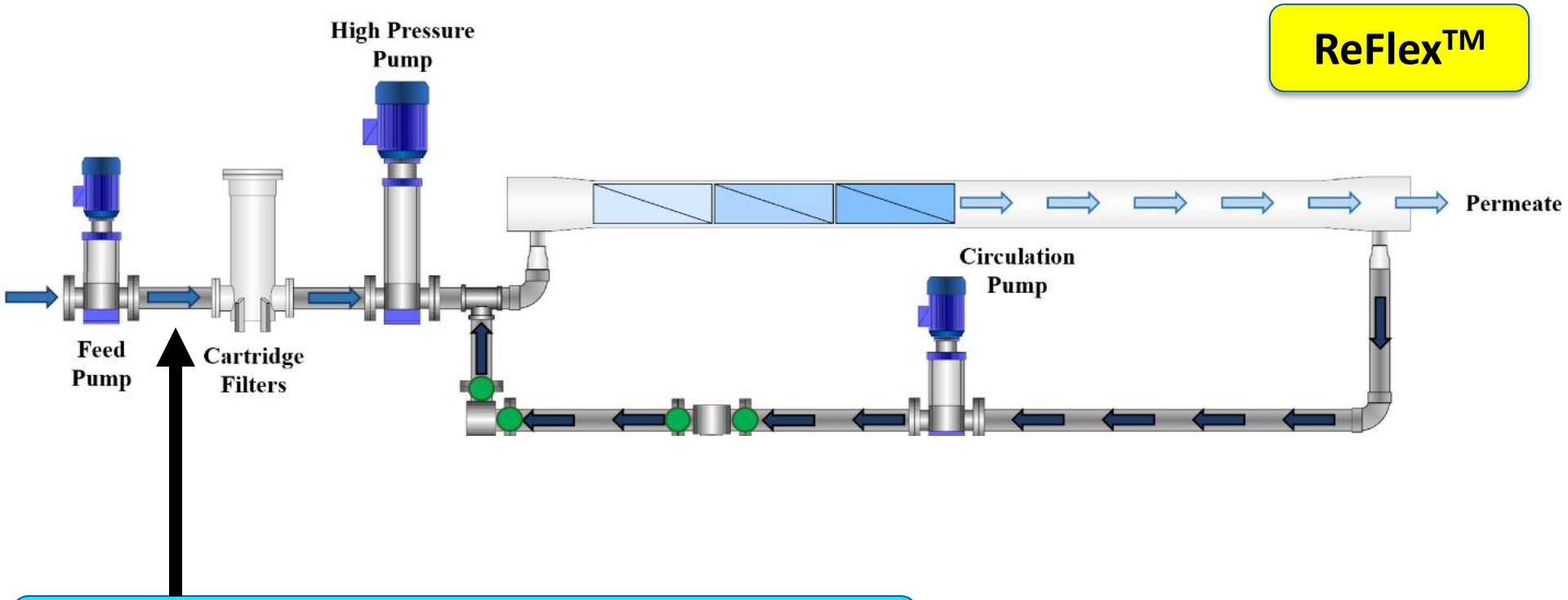


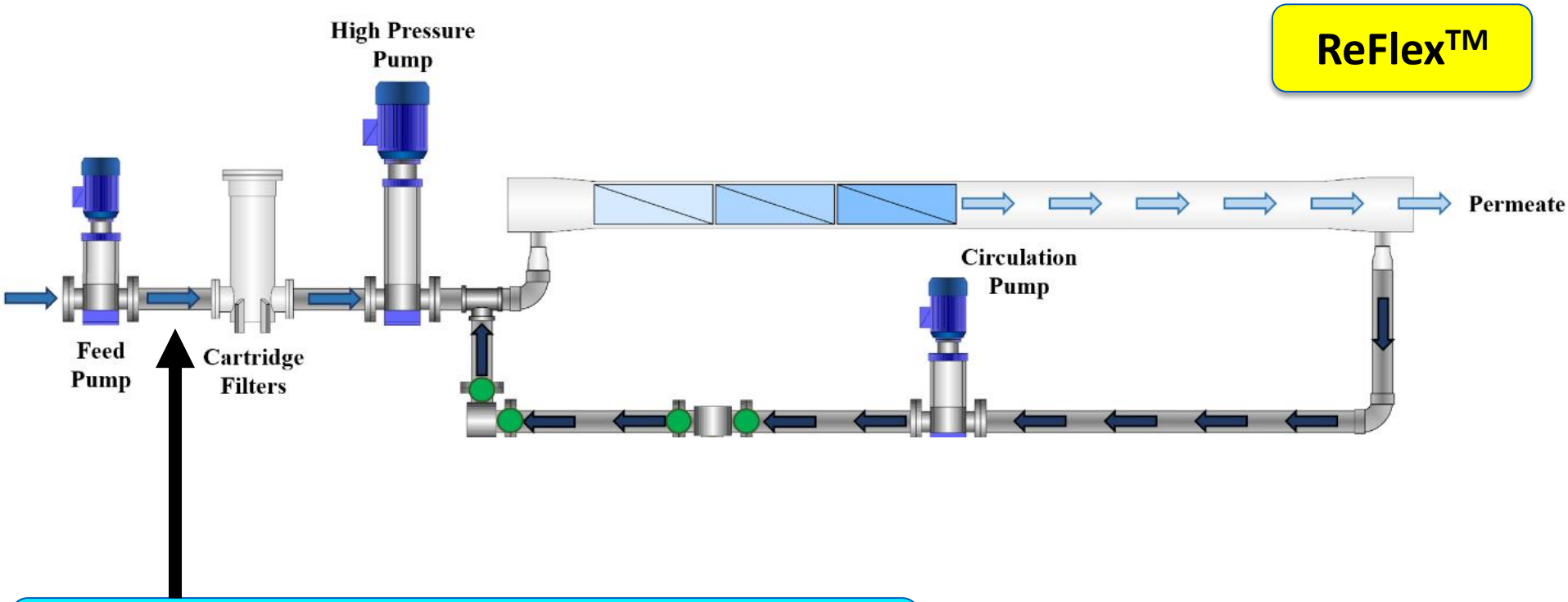
Image credit: Desalitech (DuPont)



ReFlex™

TEST 2: adjust pH to 5.7 (H_2SO_4) to control **$CaCO_3$** scale

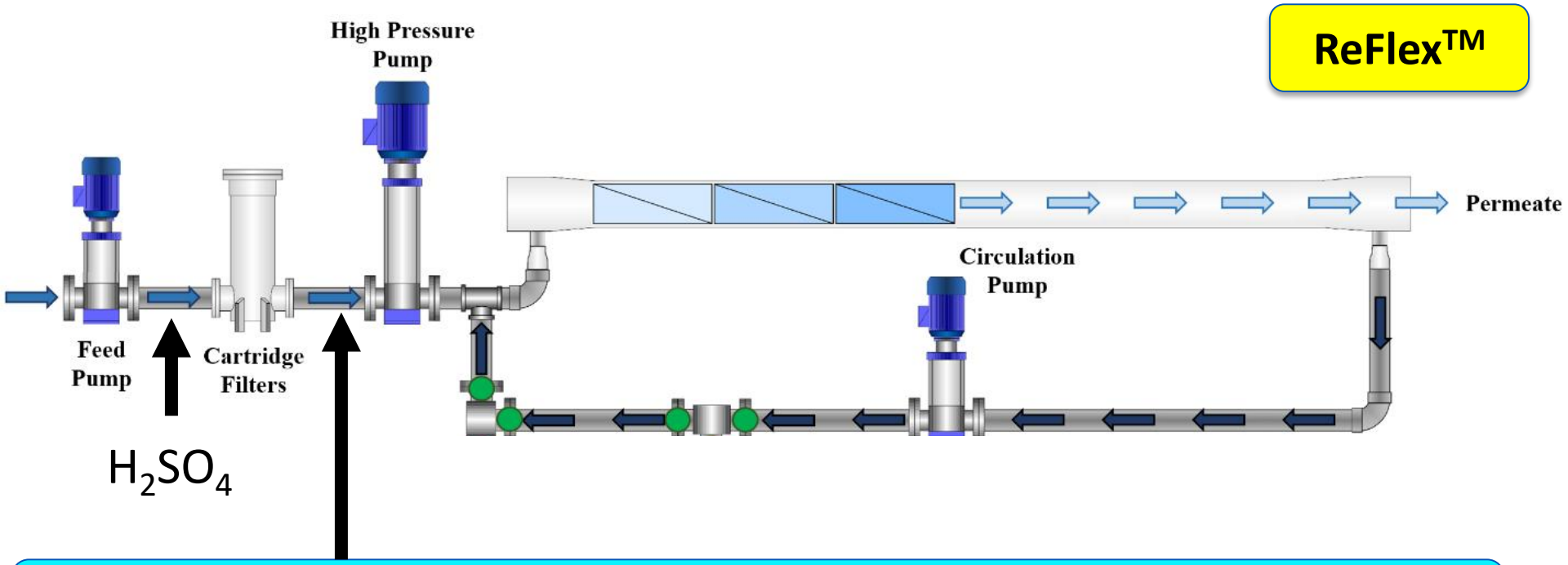
Image credit: Desalitech (DuPont)



ReFlex™

TEST 2: adjust pH to 5.7 (H_2SO_4) to control **$CaCO_3$** scale and **Si** scale

Image credit: Desalitech (DuPont)



ReFlex™

Test 3 = Optimized Antiscalant (Vitec 7400)

to control **Si** and **SO_4** scales

Tests 4 & 5 = Permeate Flushes inhibit scales

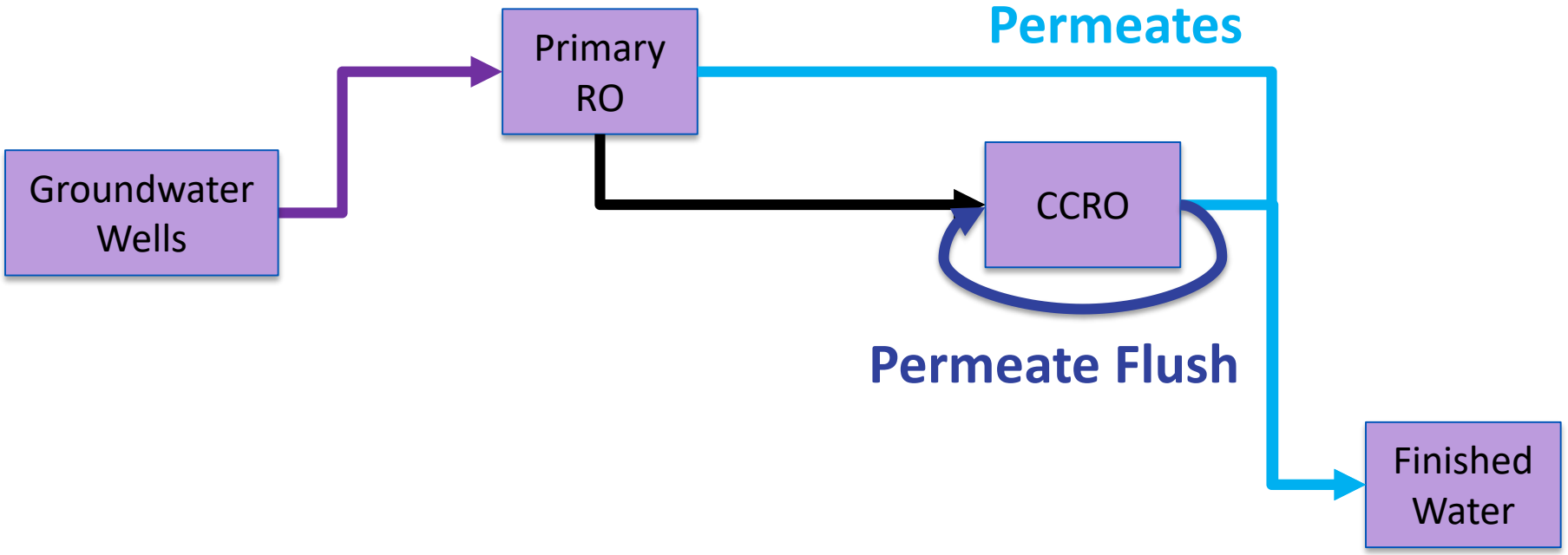
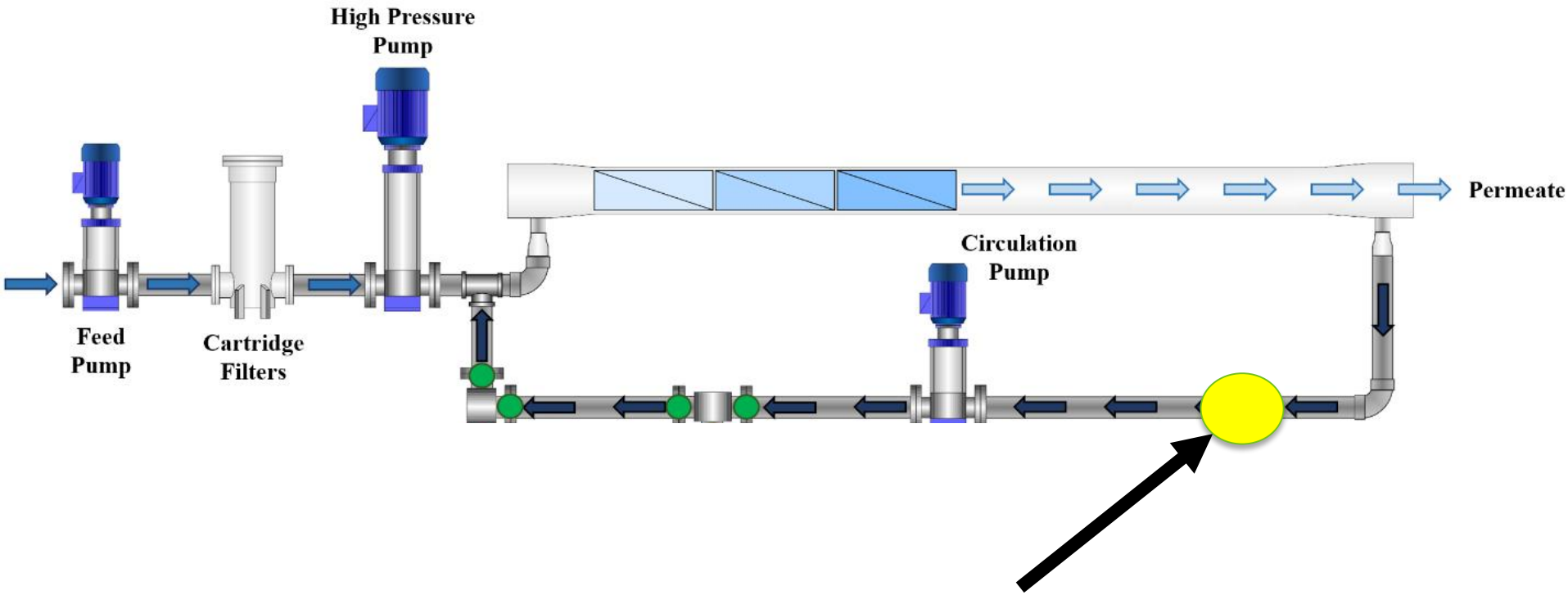
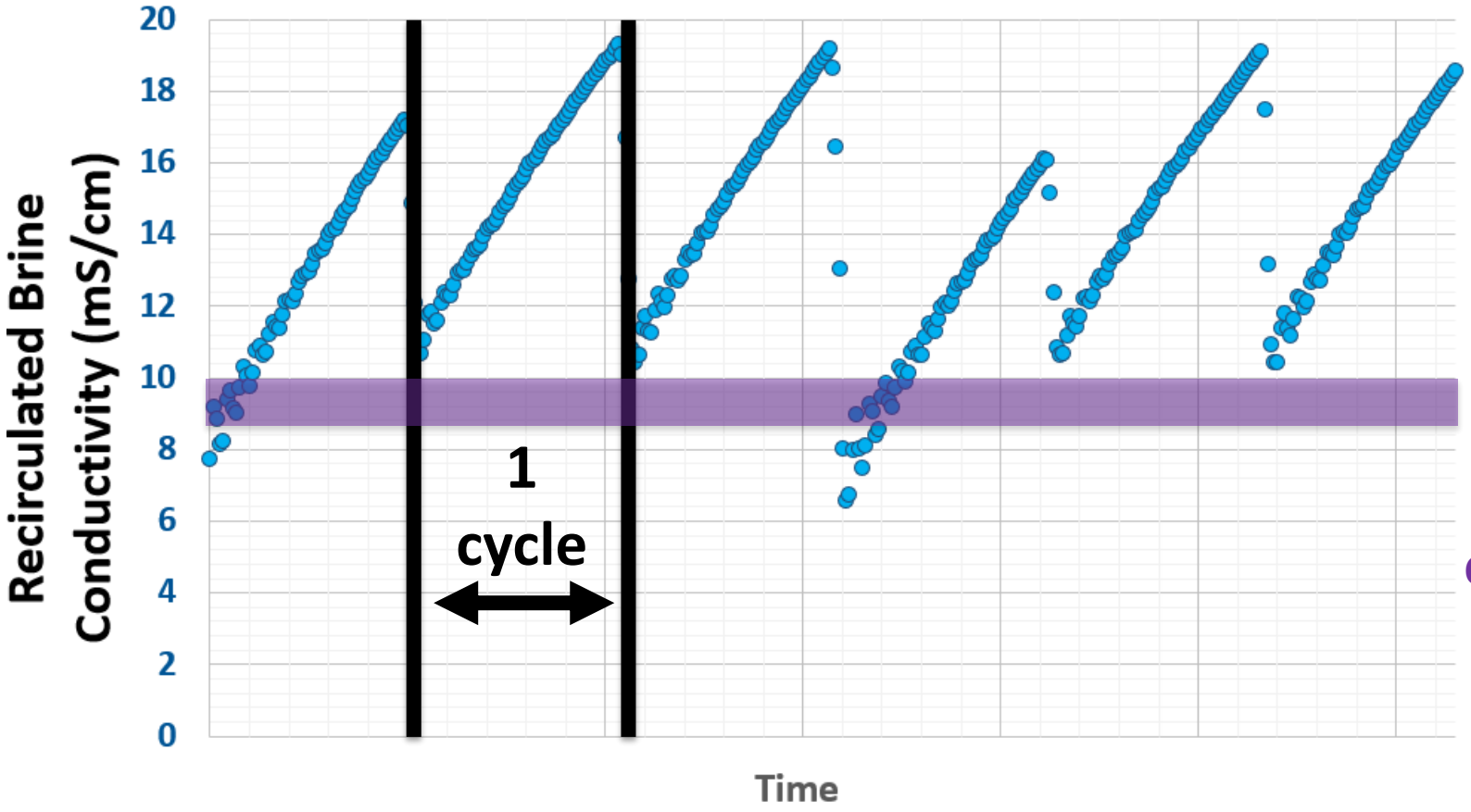
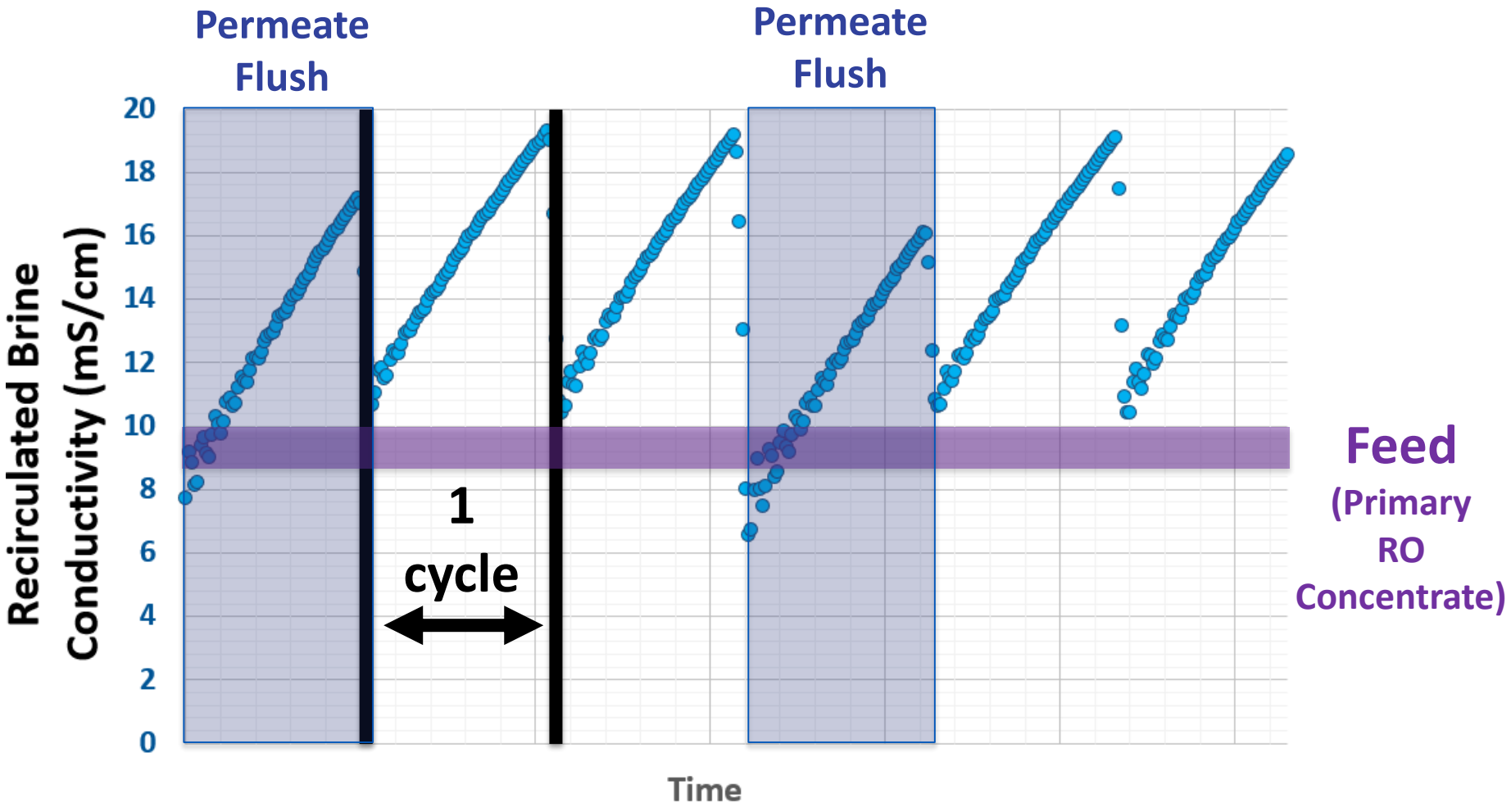


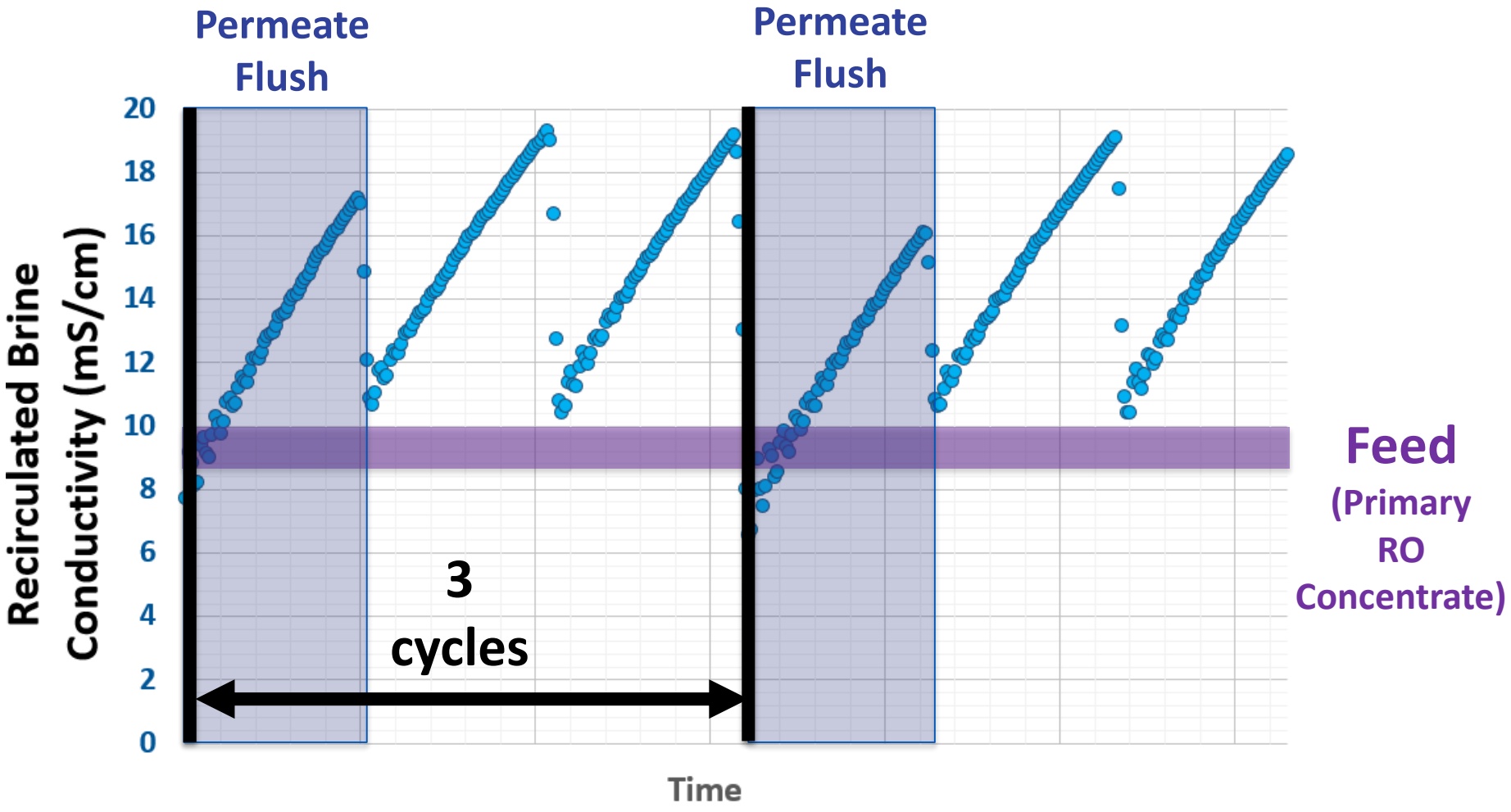
Image credit: Desalitech (DuPont)



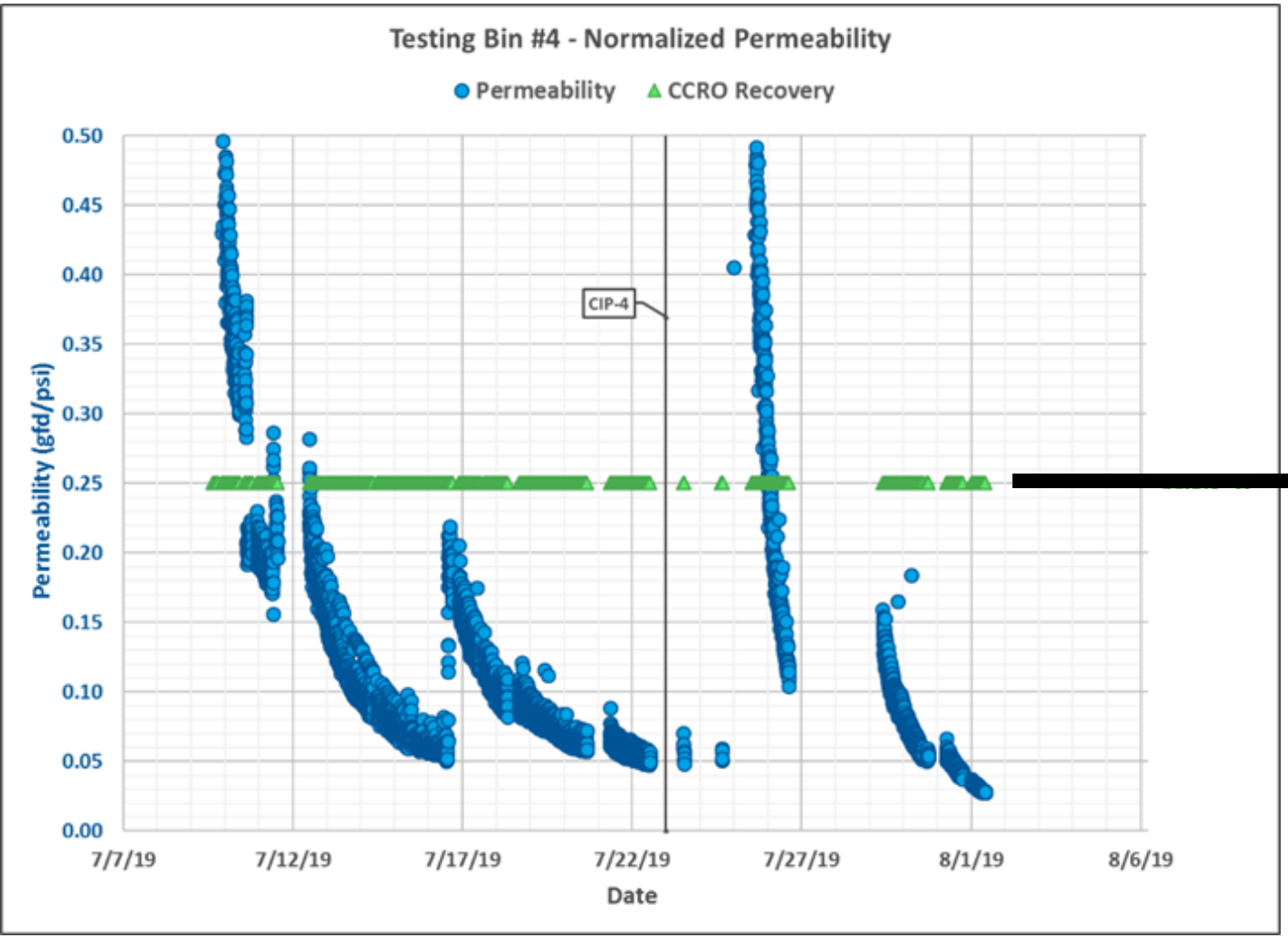
Measure Recirculated Brine Conductivity


Recirculated Brine Conductivity (mS/cm)
20
18
16
14
12
10
8
6
4
2
0
1 cycle
Time
Feed
(Primary RO Concentrate)


Permeate Flush
Permeate Flush
Recirculated Brine Conductivity (mS/cm)
20
18
16
14
12
10
8
6
4
2
0
1 cycle
Time
Feed
(Primary RO Concentrate)


Permeate Flush
Permeate Flush
Recirculated Brine Conductivity (mS/cm)
20
18
16
14
12
10
8
6
4
2
0
3 cycles
Time
Feed (Primary RO Concentrate)

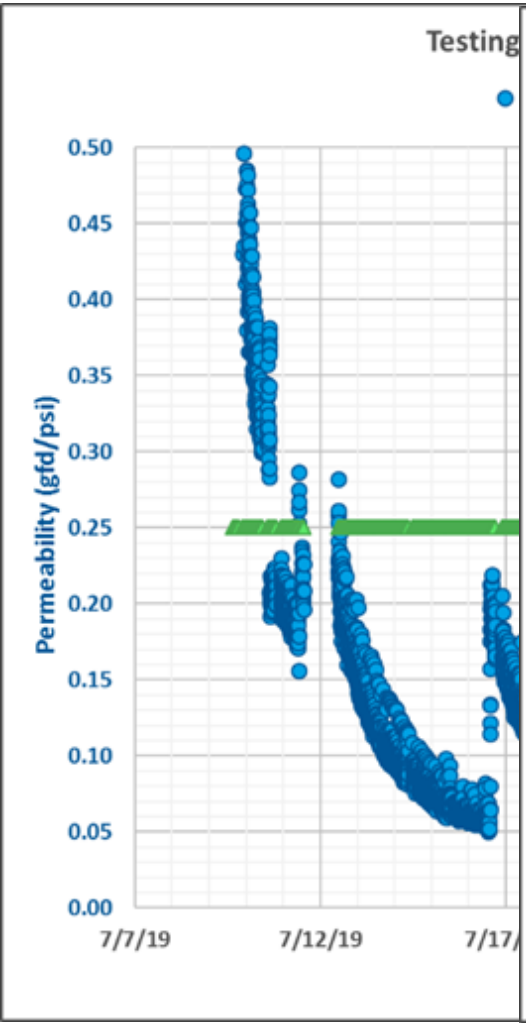
Test 4

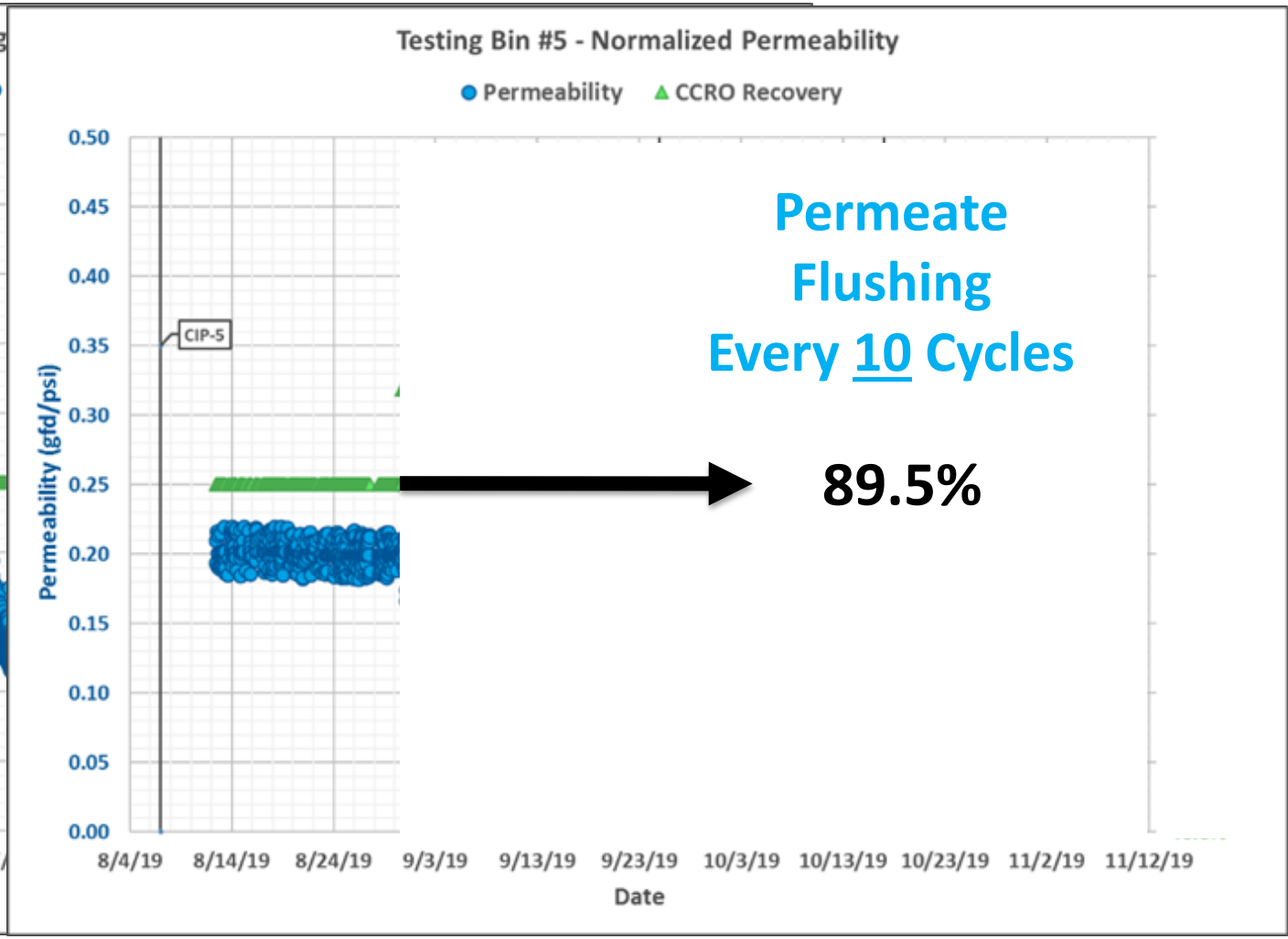


NO Permeate Flush

~90.5% Total Recovery

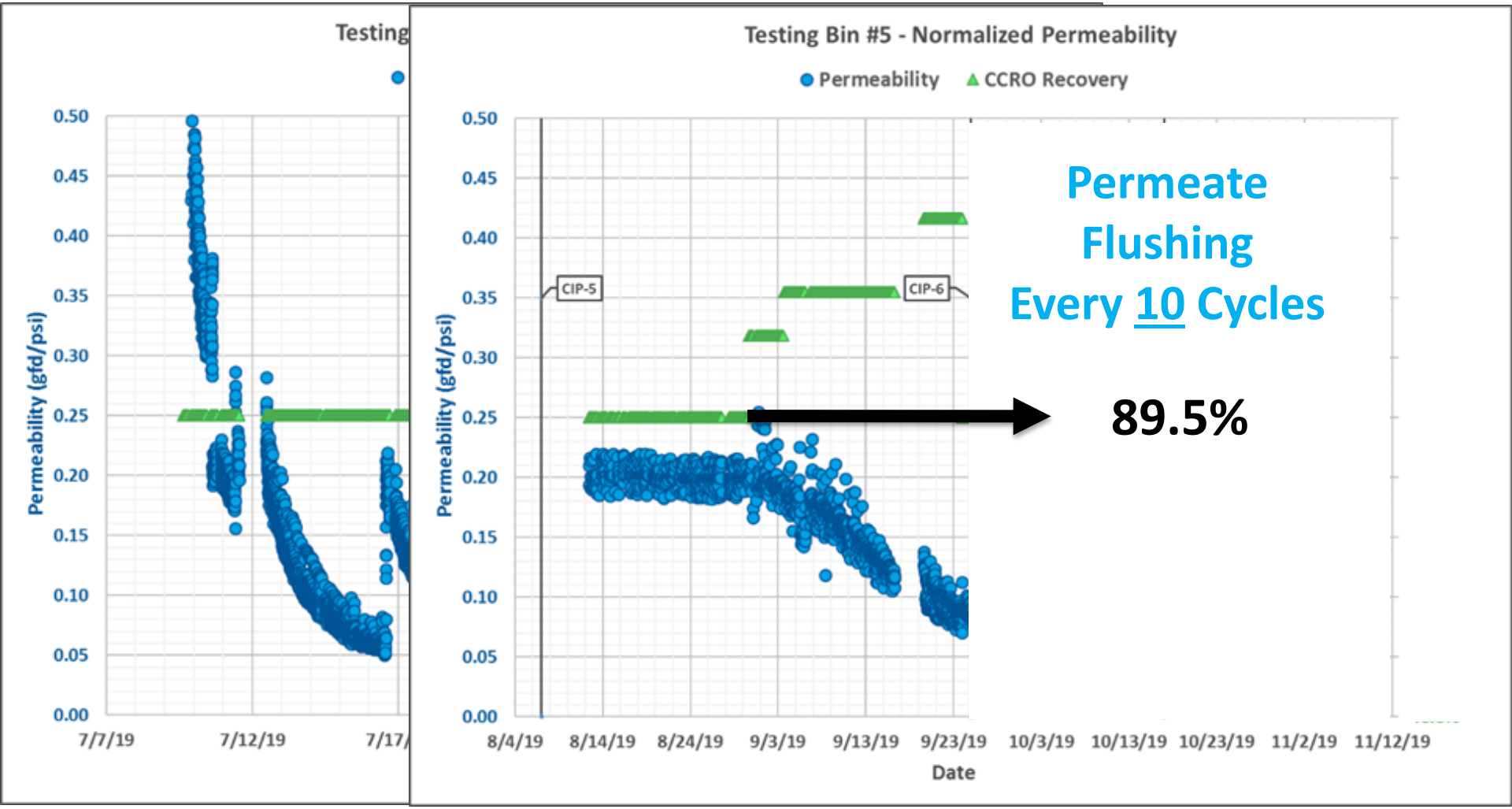
Test 5


Testing
Permeability (gfd/psi)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
7/7/19
7/12/19
7/17/


Testing Bin #5 - Normalized Permeability
Permeability
CCRO Recovery
Permeability (gfd/psi)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
CIP-5
8/4/19
8/14/19
8/24/19
9/3/19
9/13/19
9/23/19
10/3/19
10/13/19
10/23/19
11/2/19
11/12/19
Date
Permeate
Flushing
Every 10 Cycles
89.5%

Test 4

Test 5

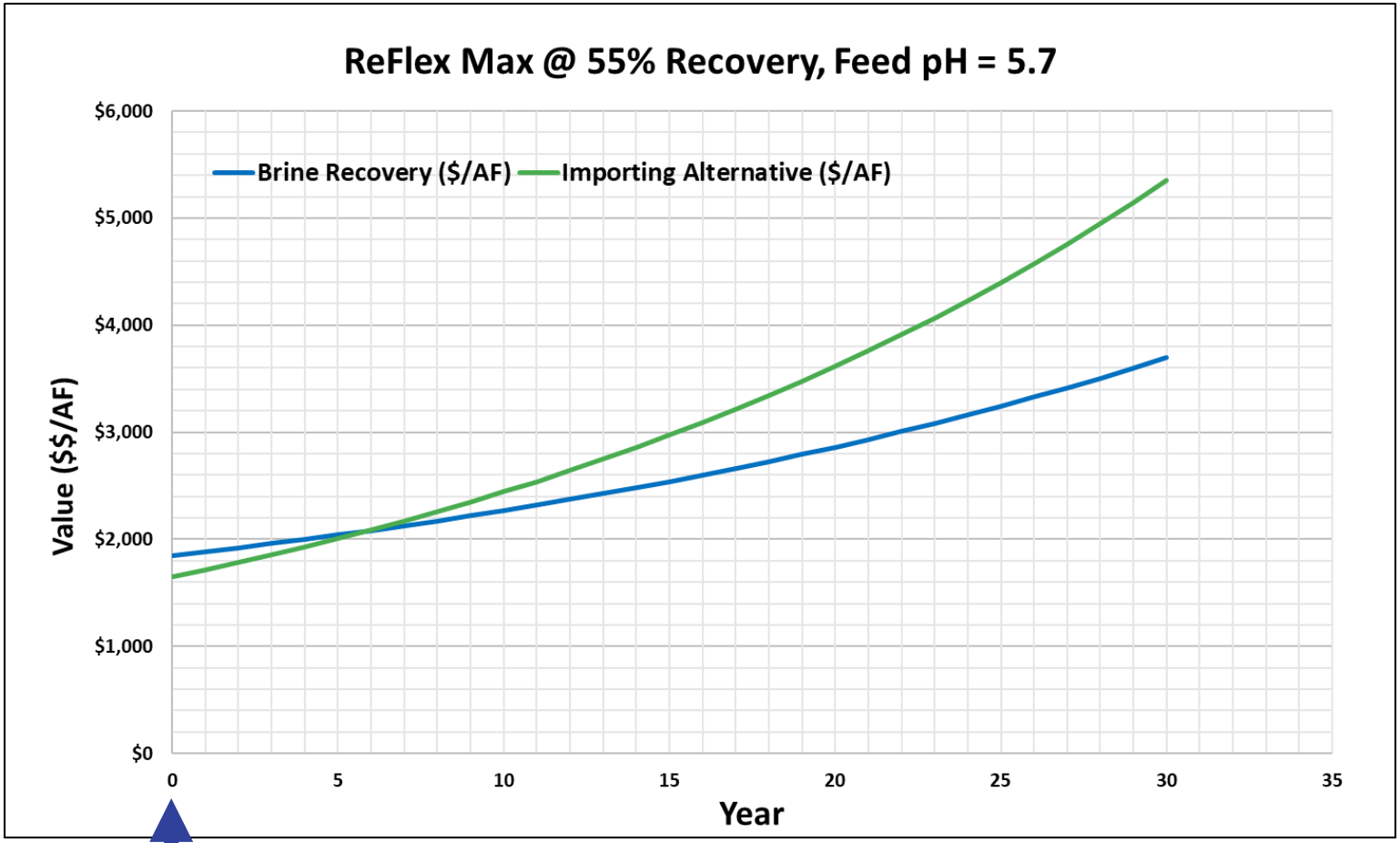

Testing
Testing Bin #5 - Normalized Permeability
Permeability
CCRO Recovery
Permeability (gfd/psi)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
CIP-5
CIP-6
7/7/19
7/12/19
8/4/19
8/14/19
8/24/19
9/3/19
9/13/19
9/23/19
10/3/19
10/13/19
10/23/19
11/2/19
11/12/19
Date
Permeate
Flushing
Every 10 Cycles
89.5%

Phase 1 – Key Takeaways

- **Phase 1**: ReFlex™ achieved 89.5% total recovery
  - **Recovery Type**: **Brine**
  - **Chemical Pre-treatment**: **H_2SO_4 and Antiscalant (Vitec 7400)**
  - **Novel Operations: Periodic Permeate Flushing**
  - **Brine Management: Acidify to ~pH 6**

- **For Phase 2**
  - Optimize **permeate flushes** to achieve 90%+ total recovery
  - Use ReFlex™ MAX system for hydraulic flexibility required for brine recovery

Class 5 Conceptual Costs for MAX



Testing Phases

PHASE 1

- ❑ 2018 – 2019
- ❑ CCRO ReFlex™ FLEX
- ❑ Primary and Brine Recovery

PHASE 2

- ❑ March 2021 – Present
- ❑ CCRO ReFlex™ MAX
- ❑ Brine Recovery only

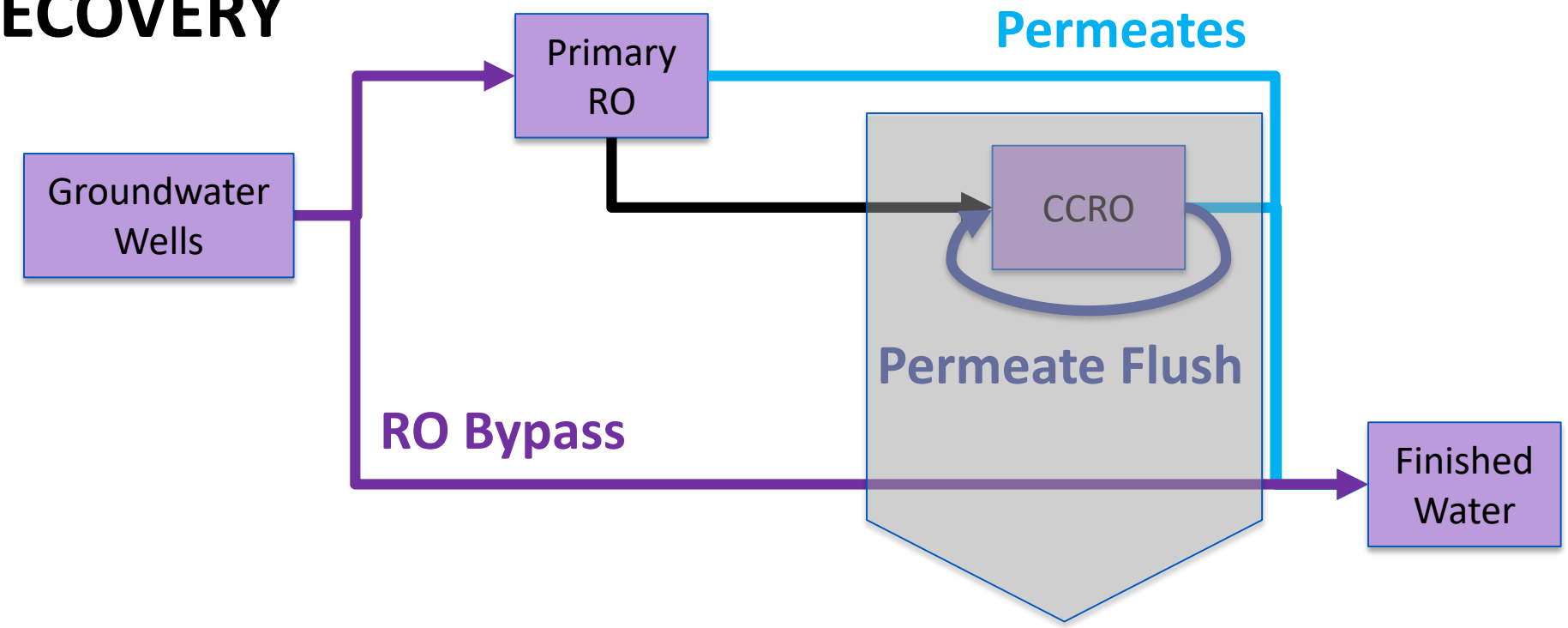
Phase 2 Progress

RO Vessel

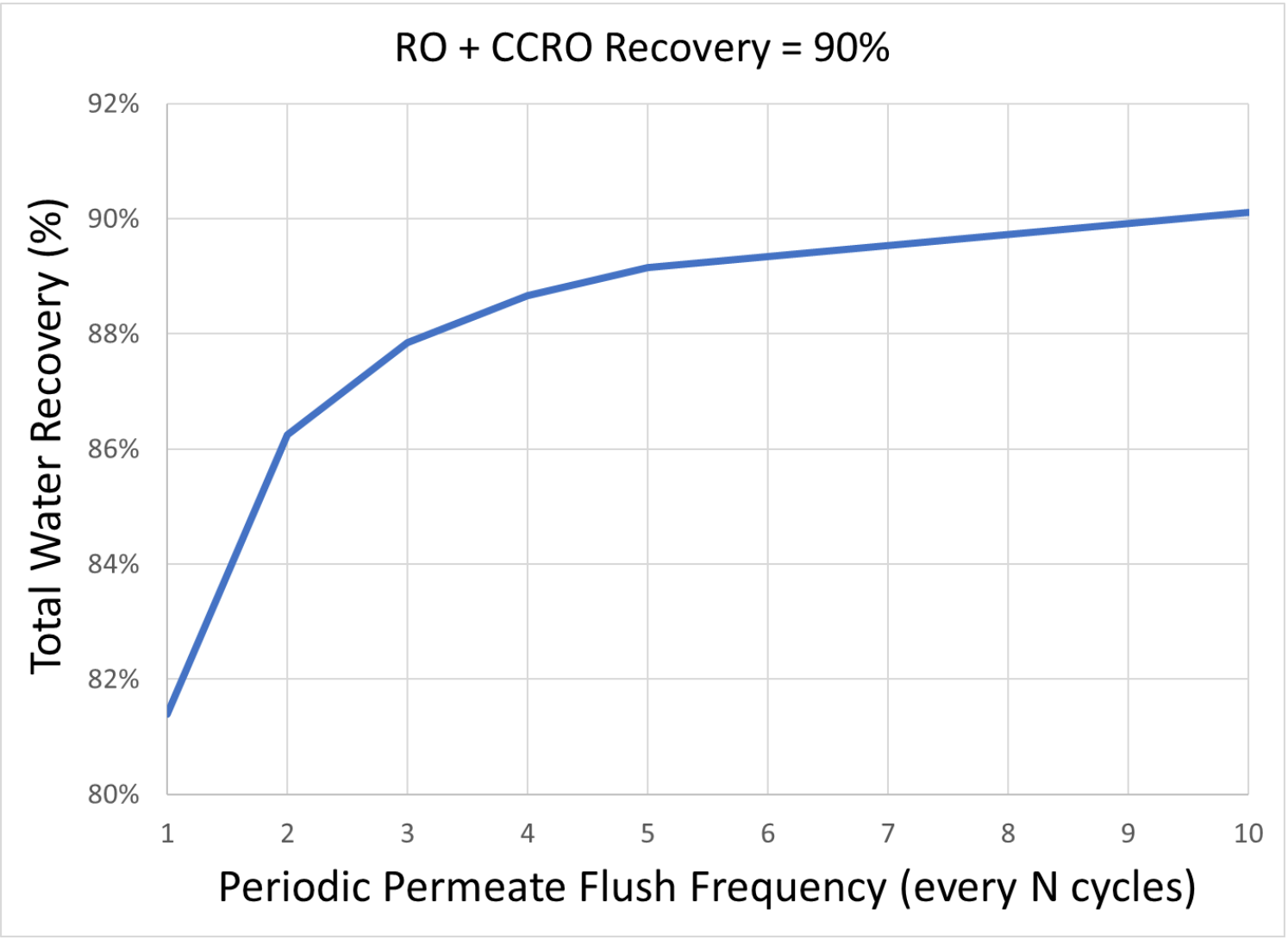
Side Conduit

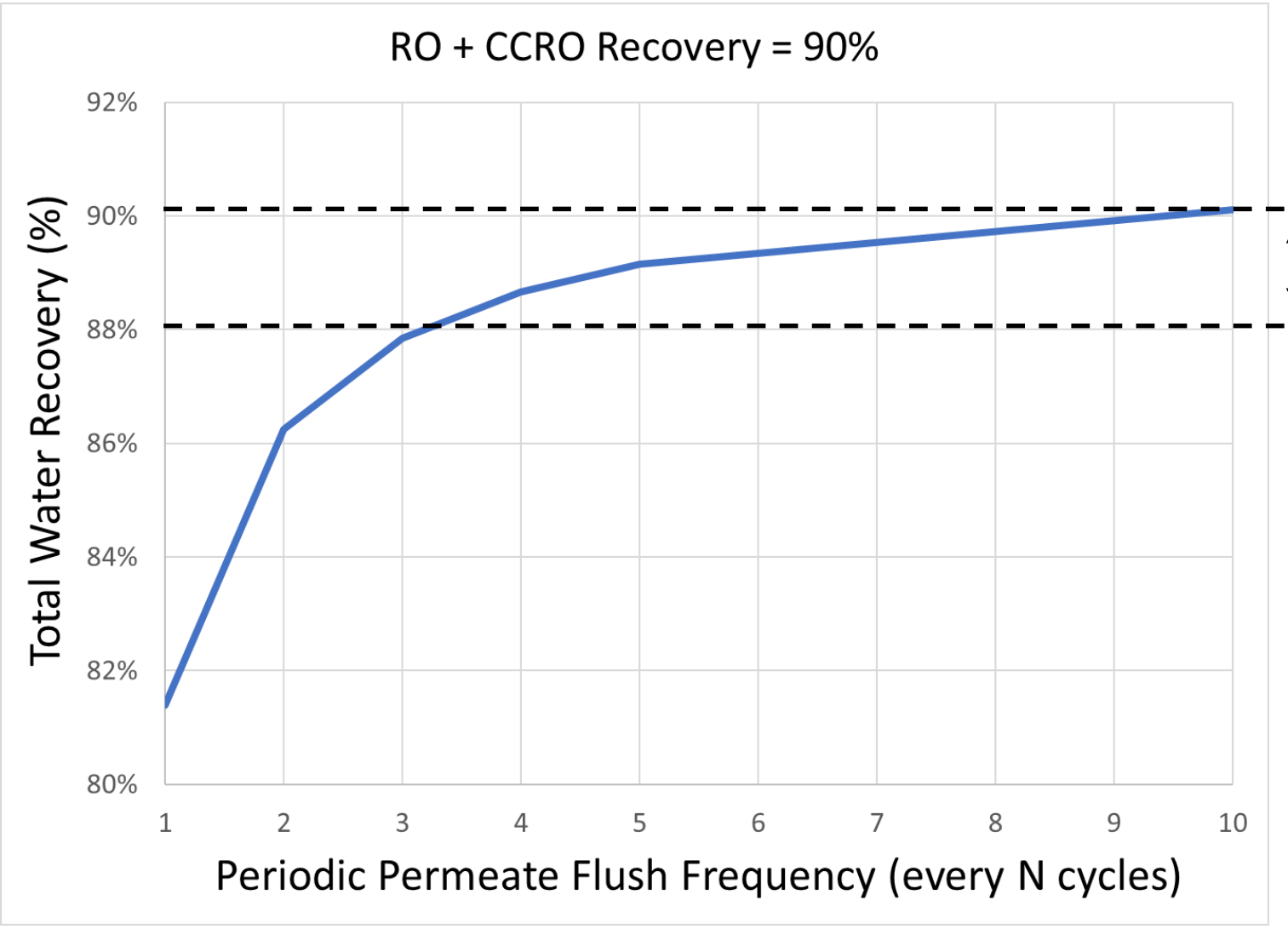
Phase 2

RECOVERY

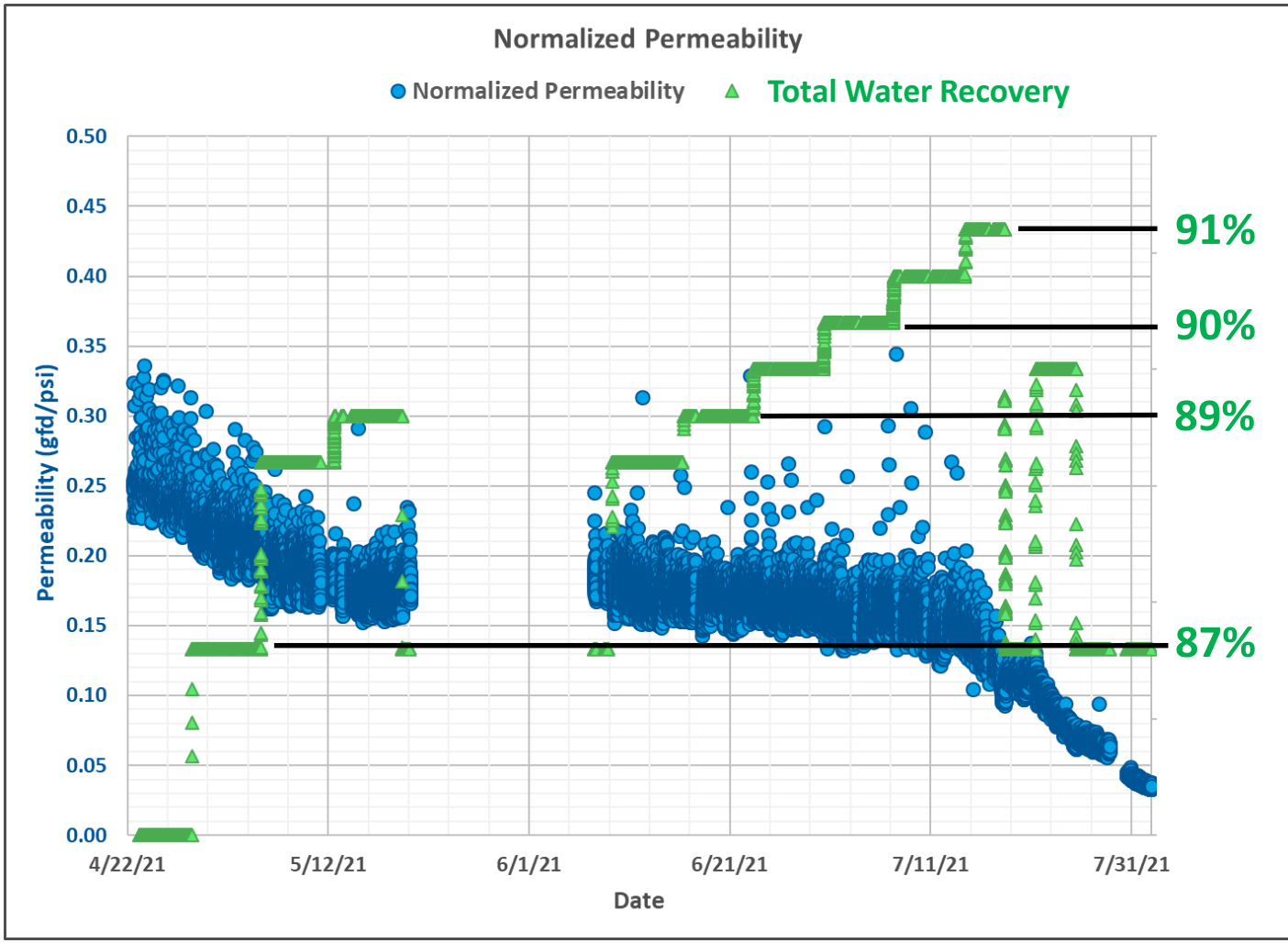


Significantly impacts recovery!

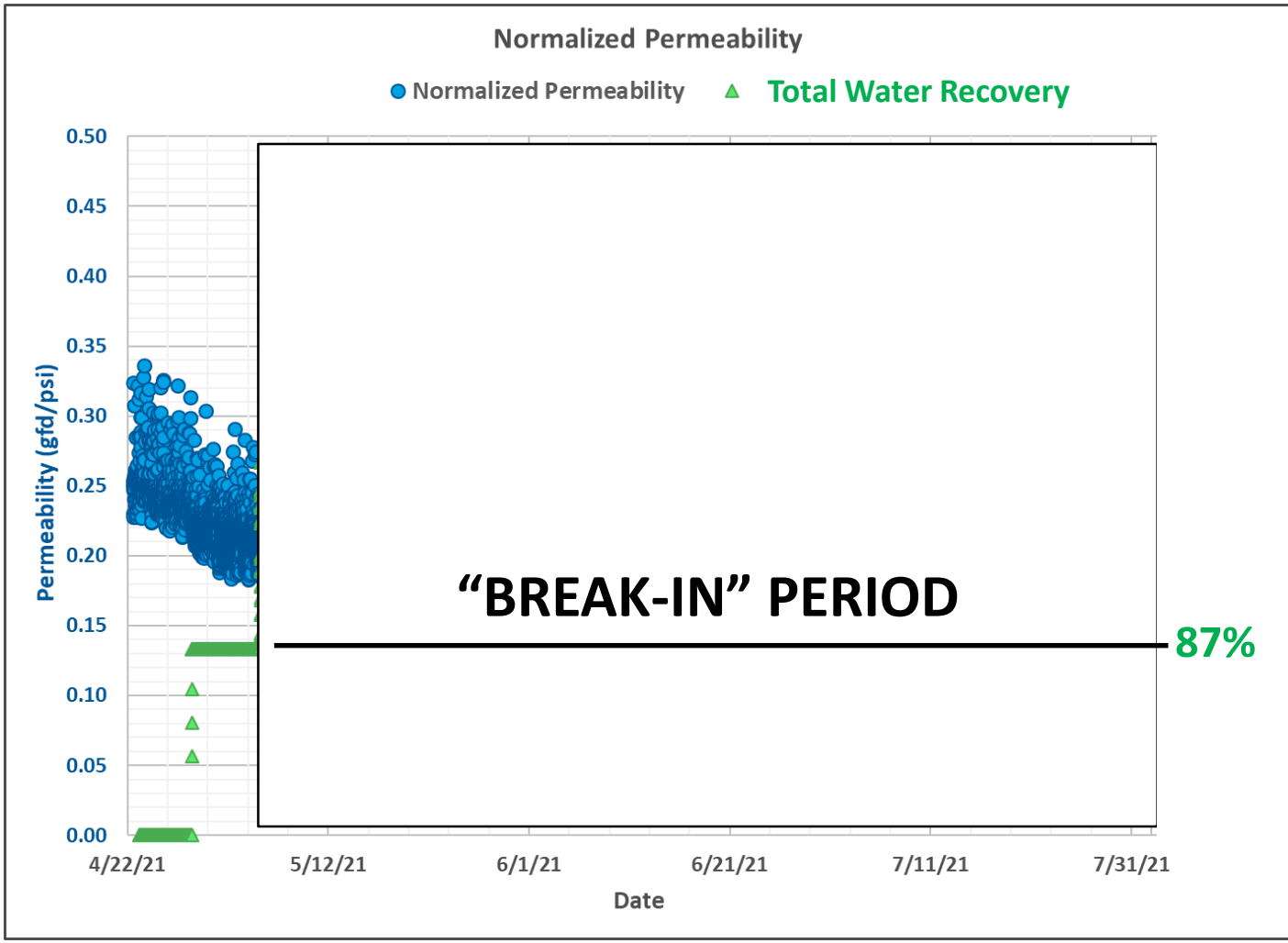

RO + CCRO Recovery = 90%
Total Water Recovery (%)
92%
90%
88%
86%
84%
82%
80%
1
2
3
4
5
6
7
8
9
10
Periodic Permeate Flush Frequency (every N cycles)


RO + CCRO Recovery = 90%
92%
90%
88%
86%
84%
82%
80%
Total Water Recovery (%)
1
2
3
4
5
6
7
8
9
10
Periodic Permeate Flush Frequency (every N cycles)
2% difference in recovery

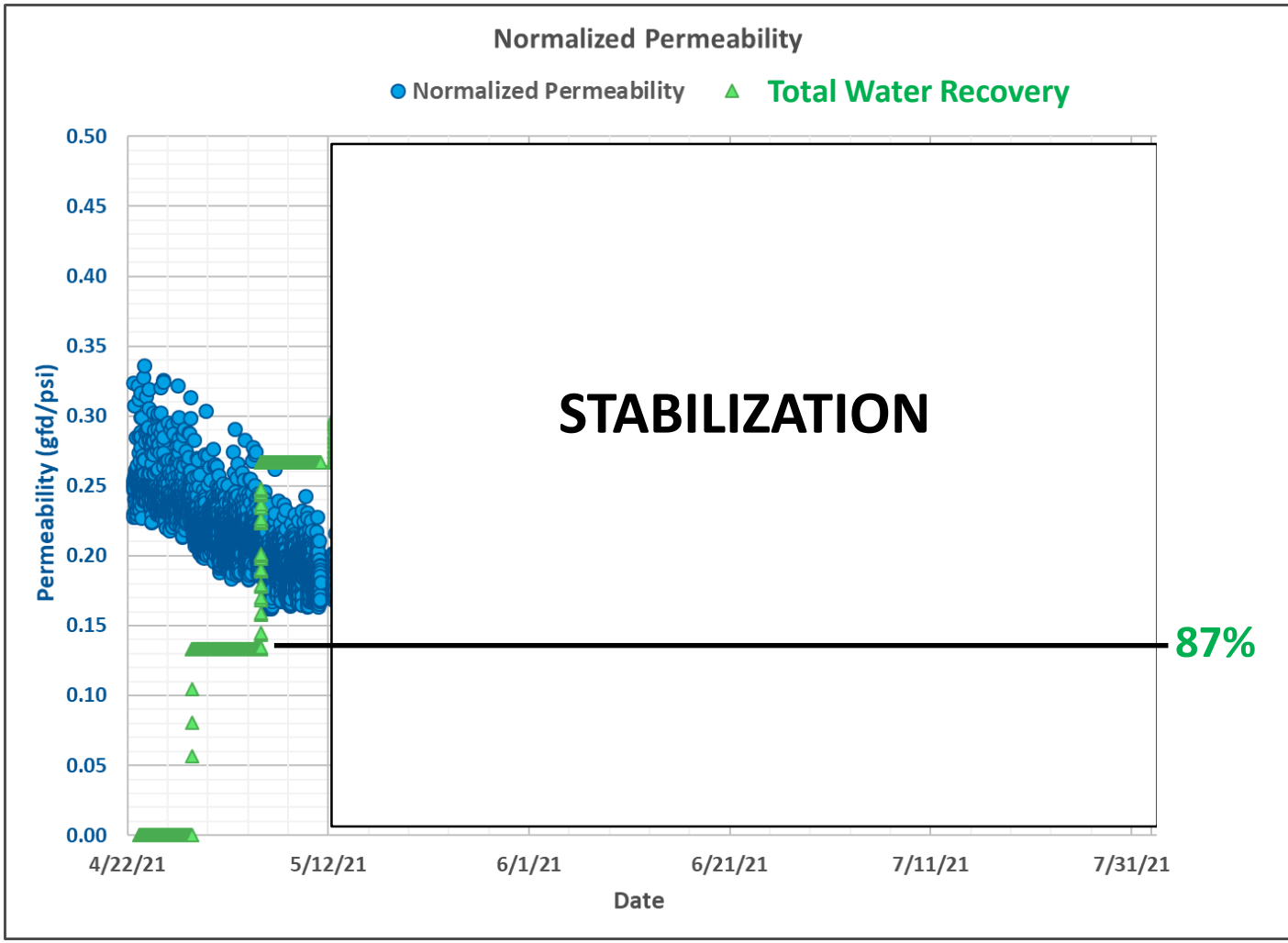
Permeate Flushes as Frequently As Feasible



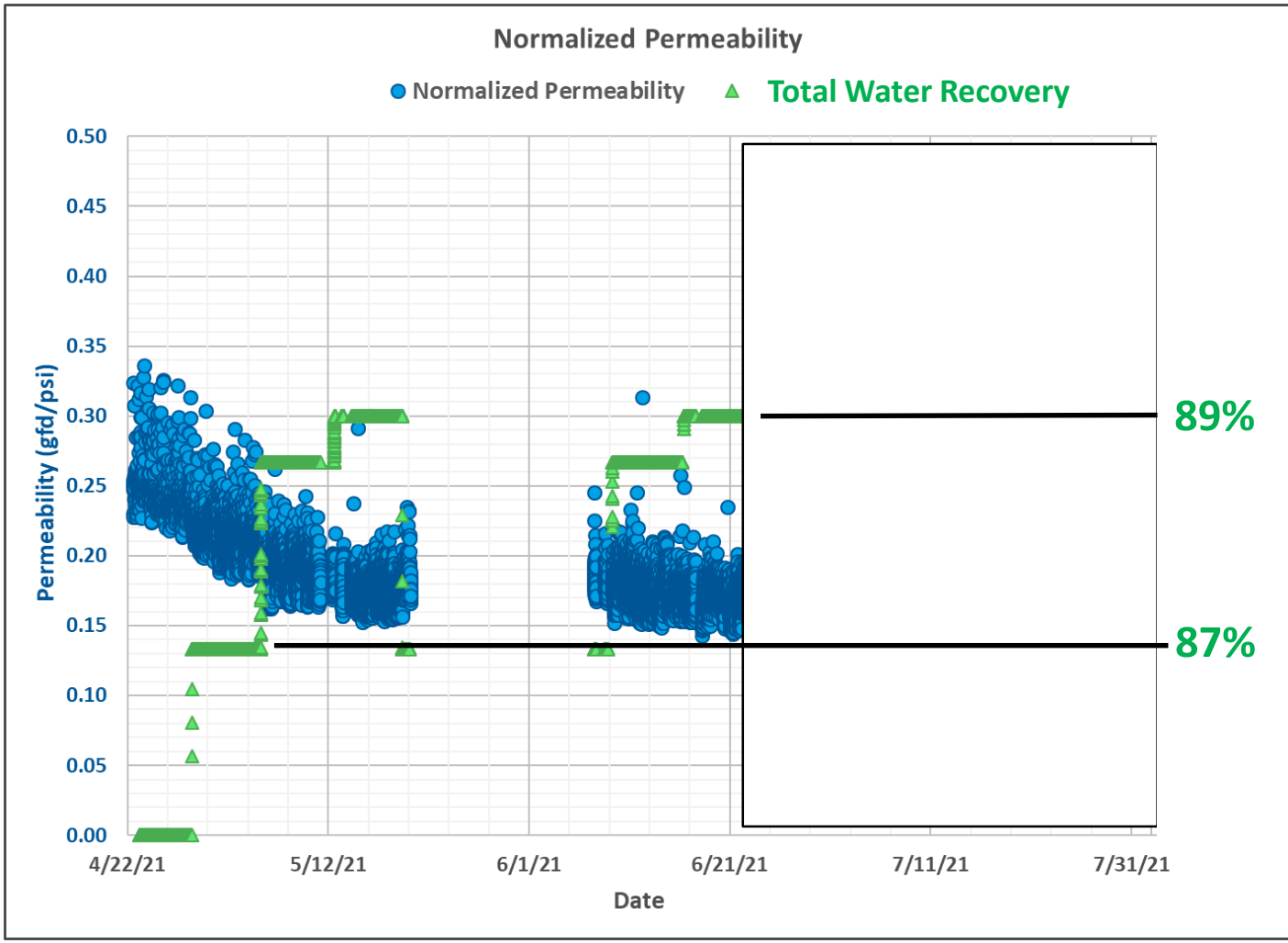
Permeate Flushes as Frequently As Feasible



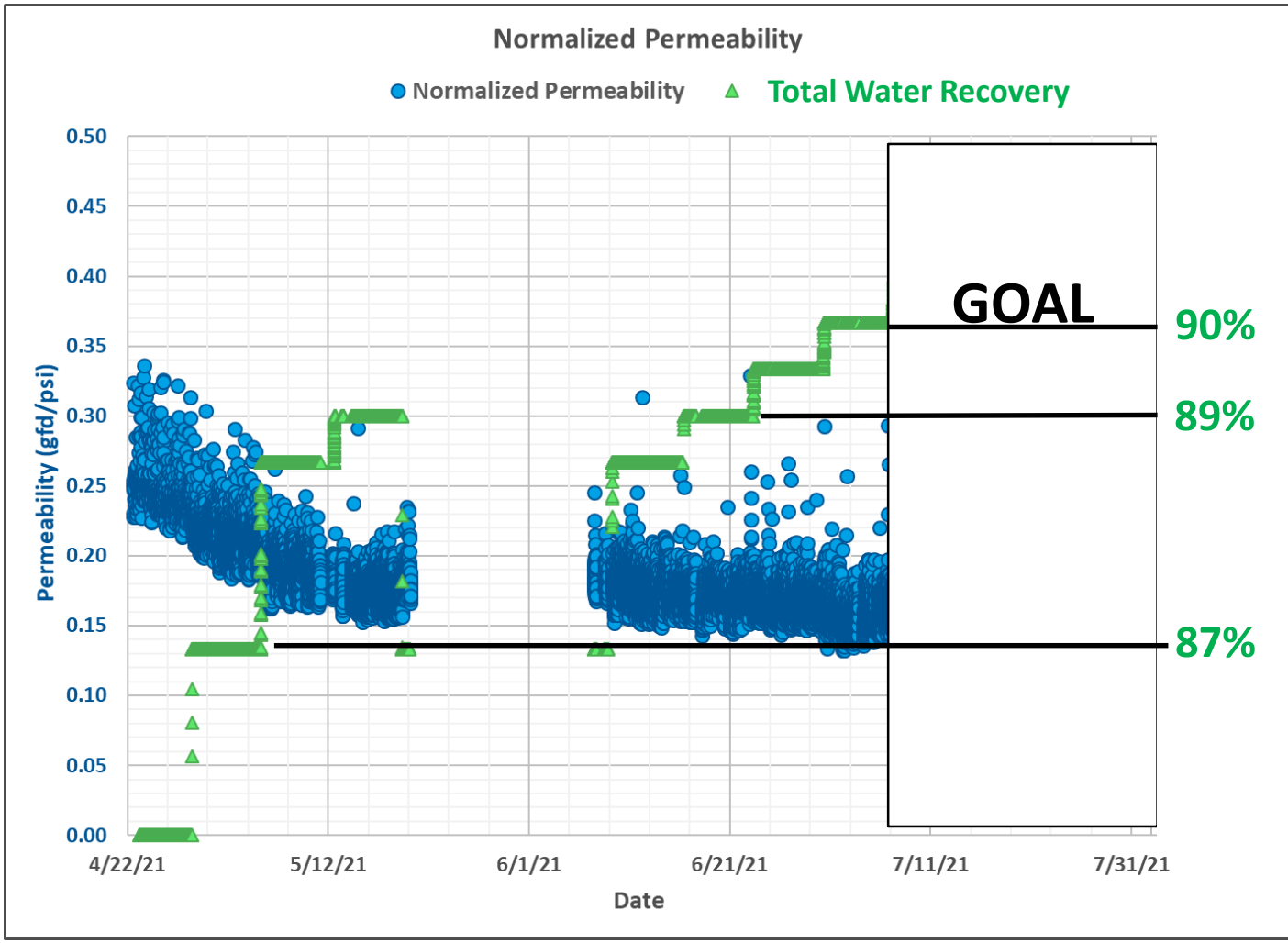
Permeate Flushes as Frequently As Feasible



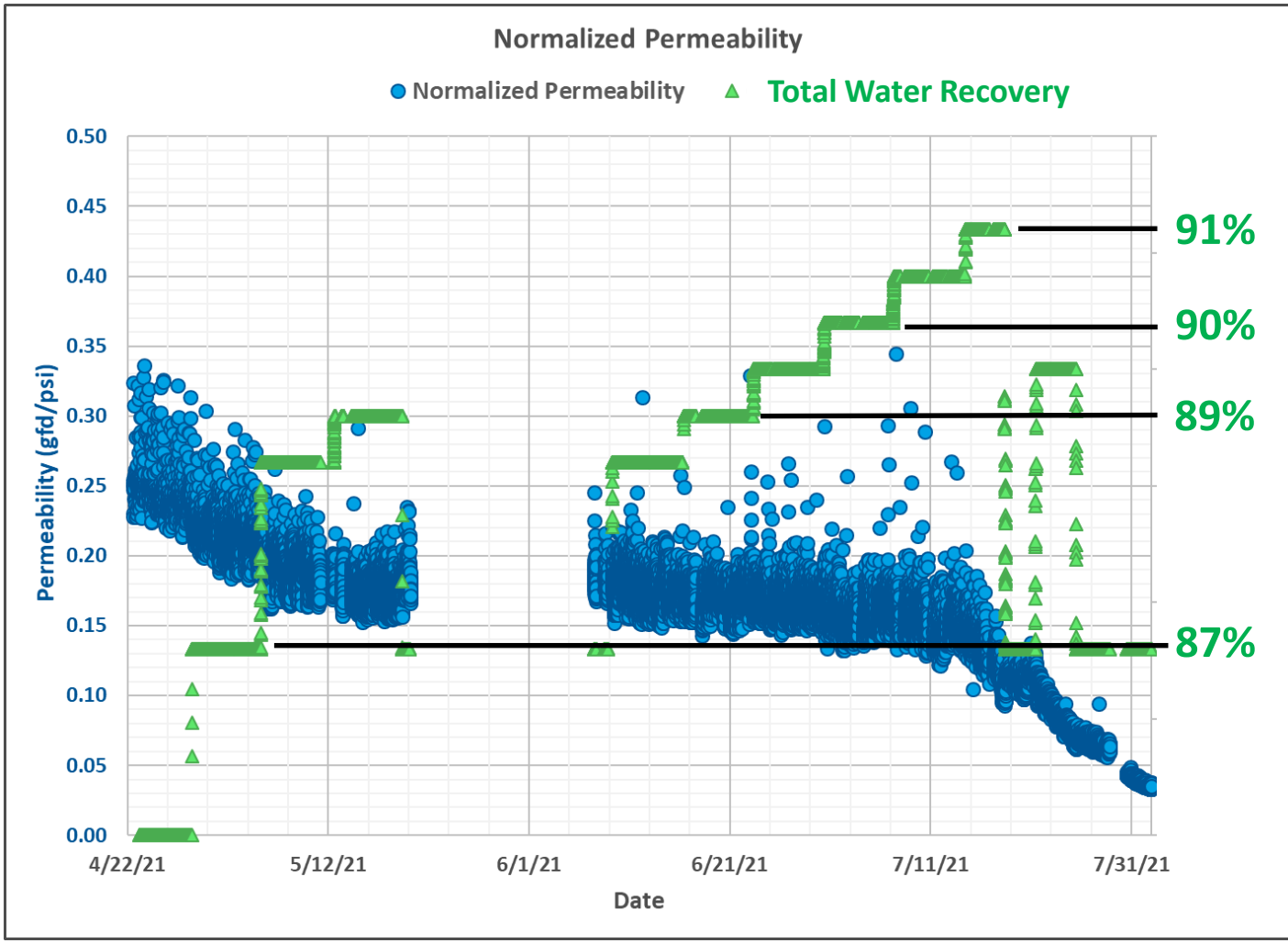
Permeate Flushes as Frequently As Feasible



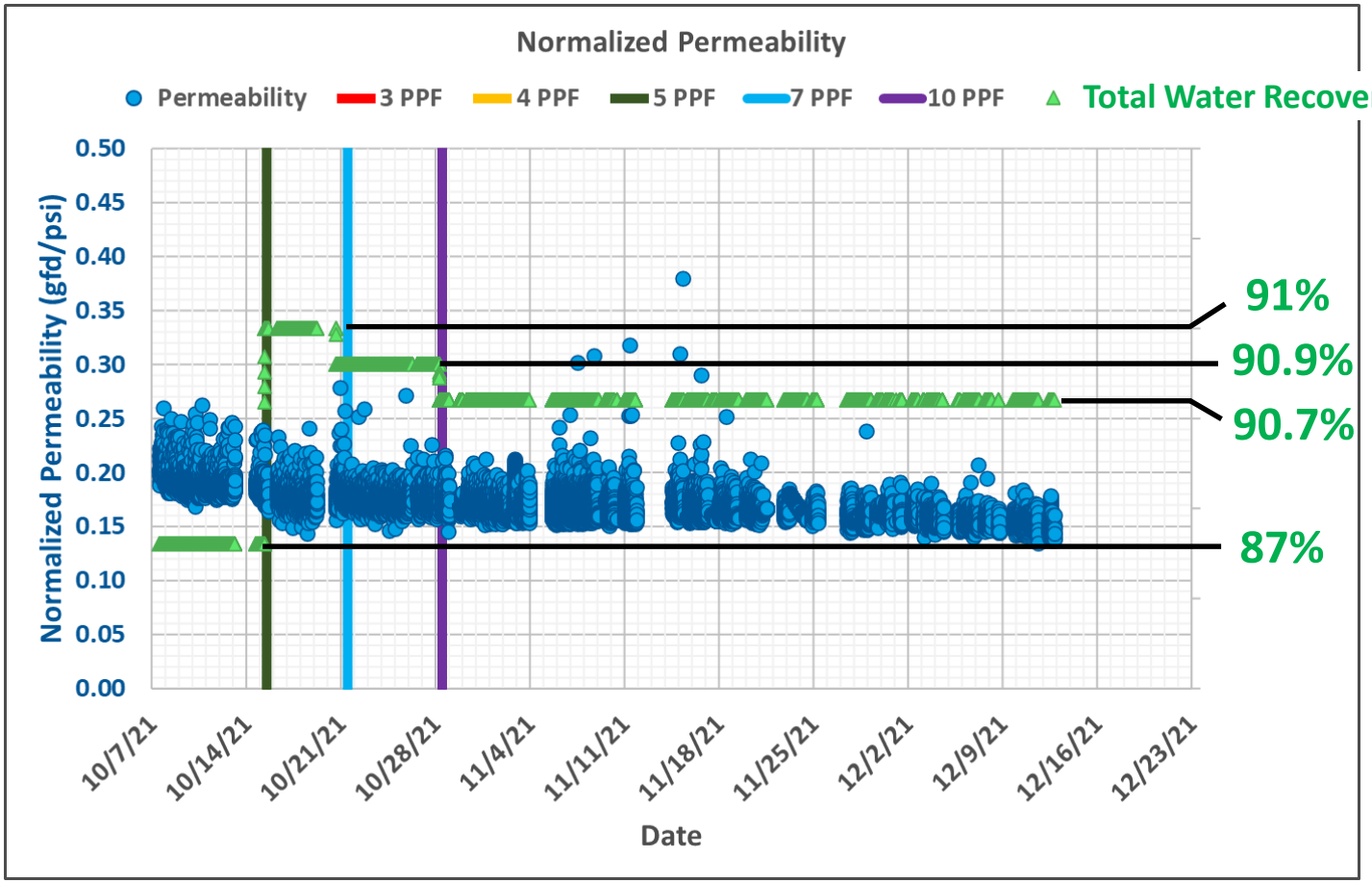
Permeate Flushes as Frequently As Feasible



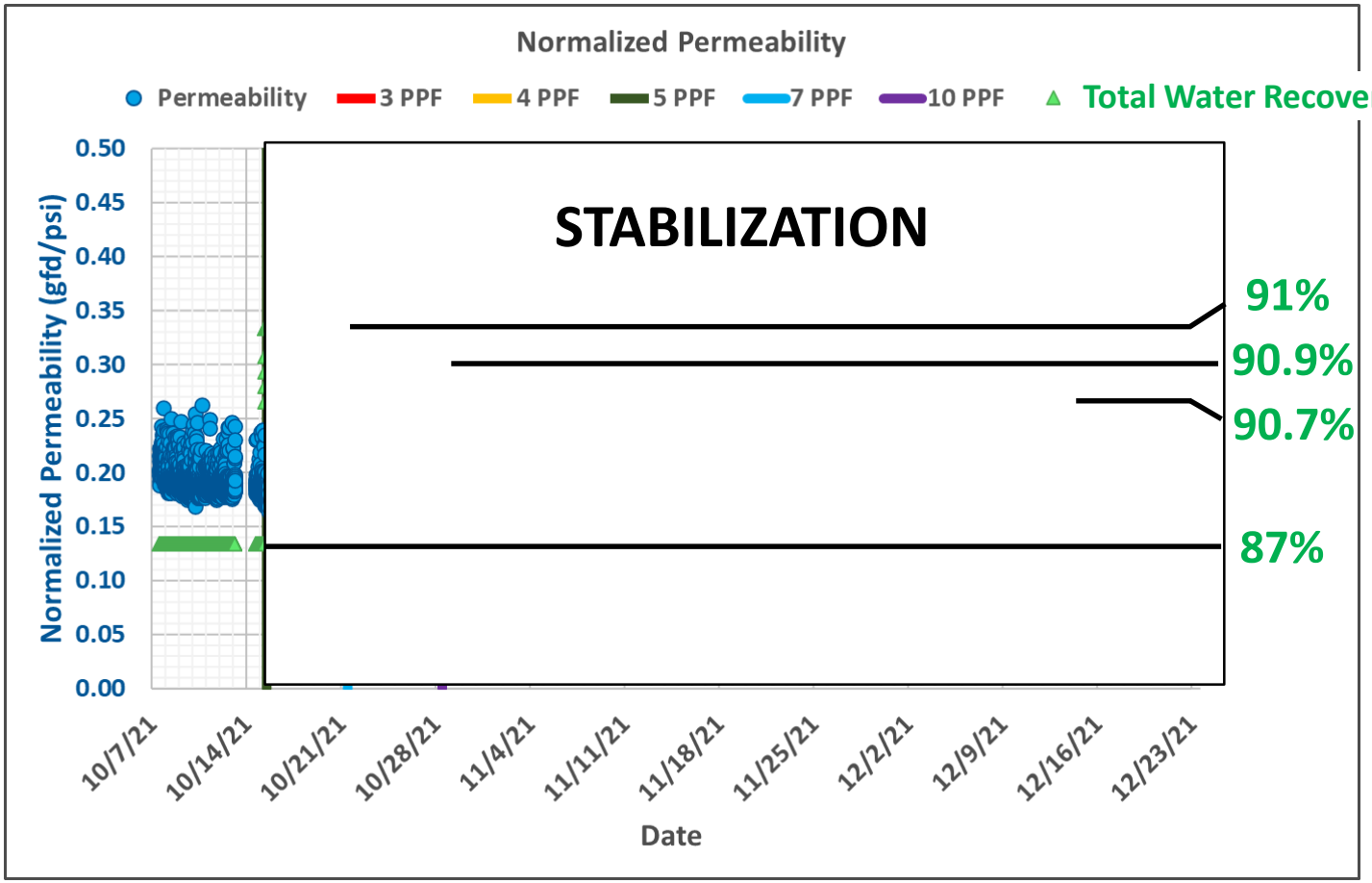
Permeate Flushes as Frequently As Feasible



Periodically Lower Permeate Flush Frequency

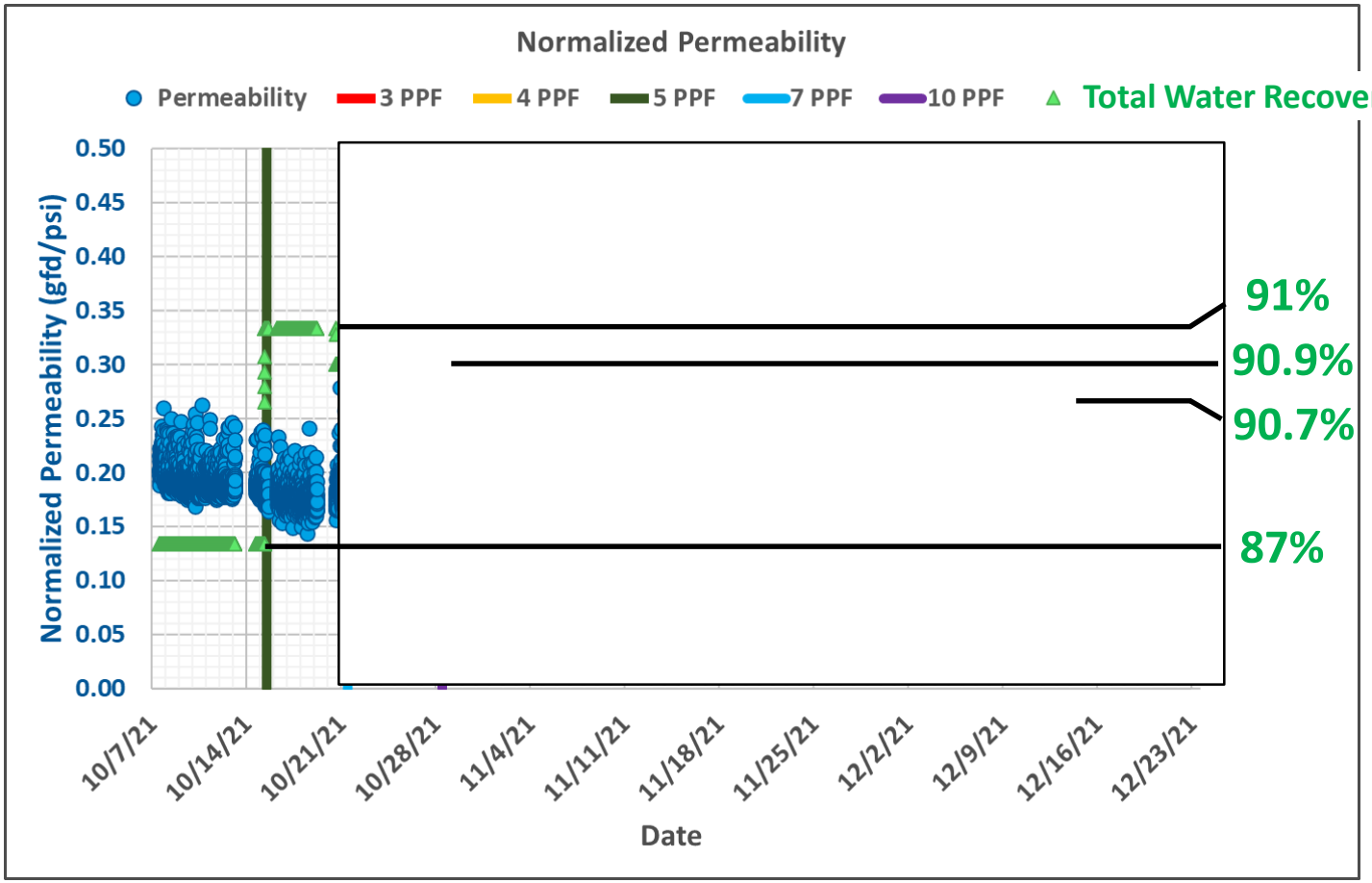


Periodically Lower Permeate Flush Frequency

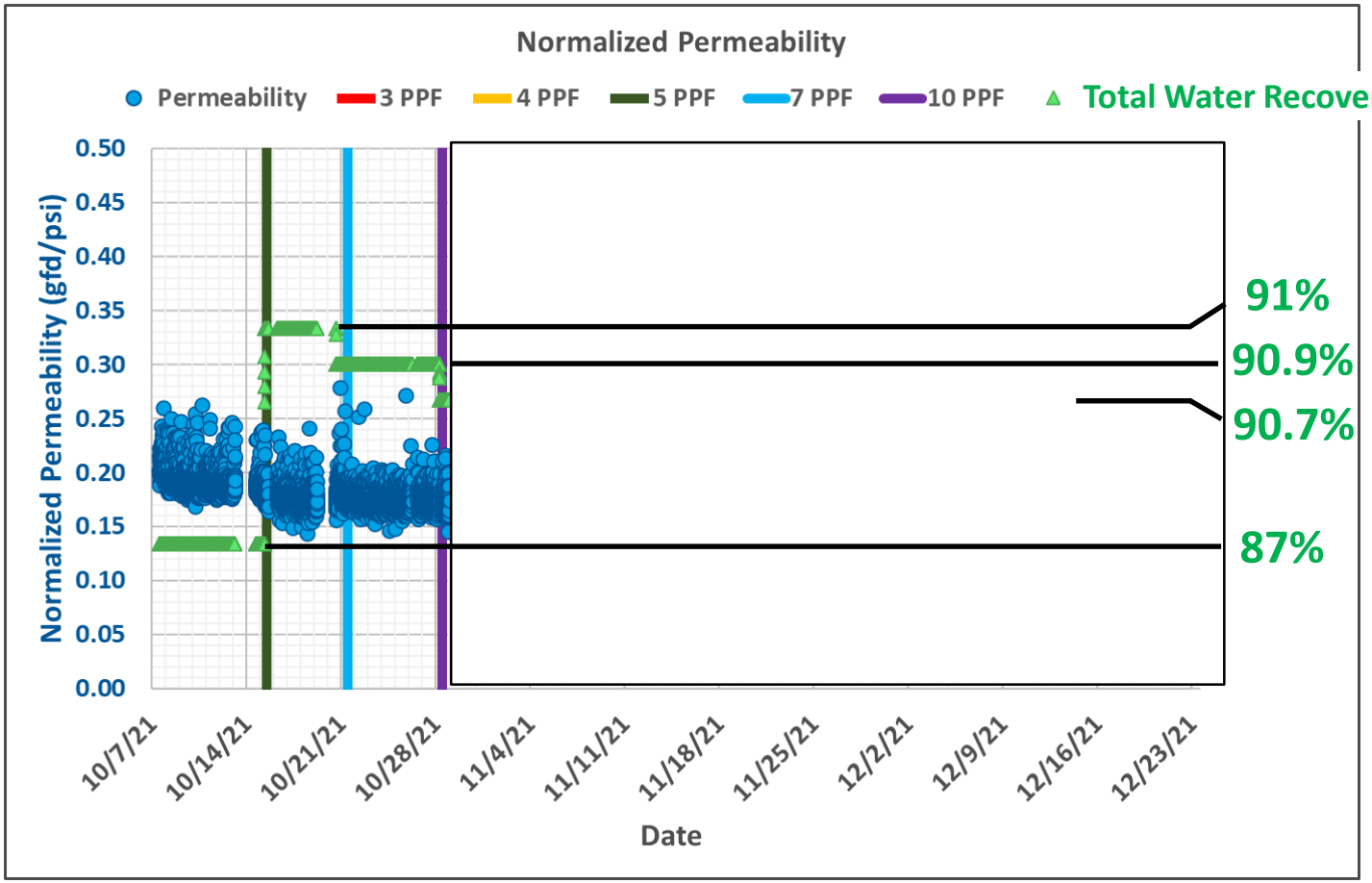


> 1.5 months

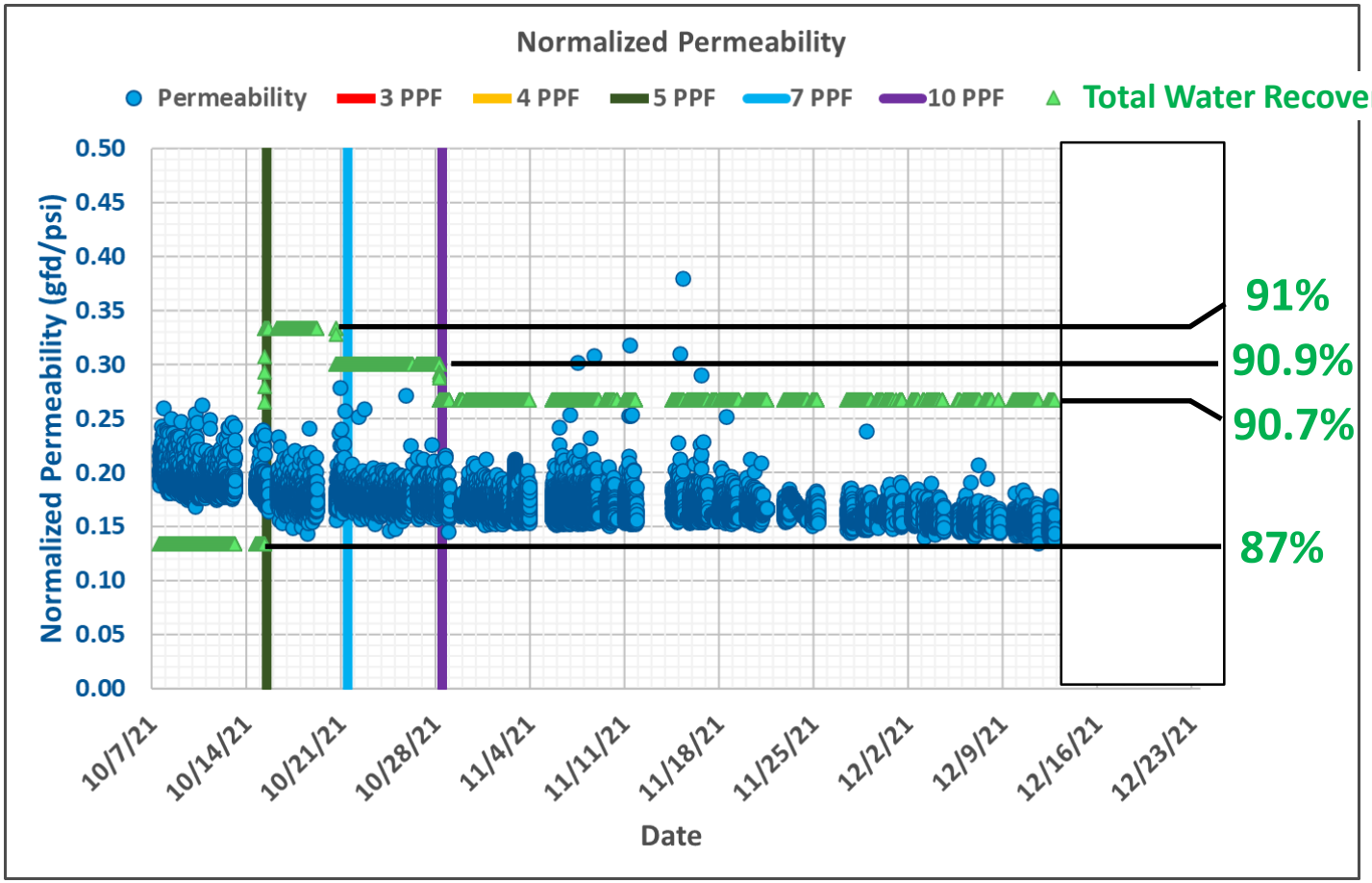
Periodically Lower Permeate Flush Frequency



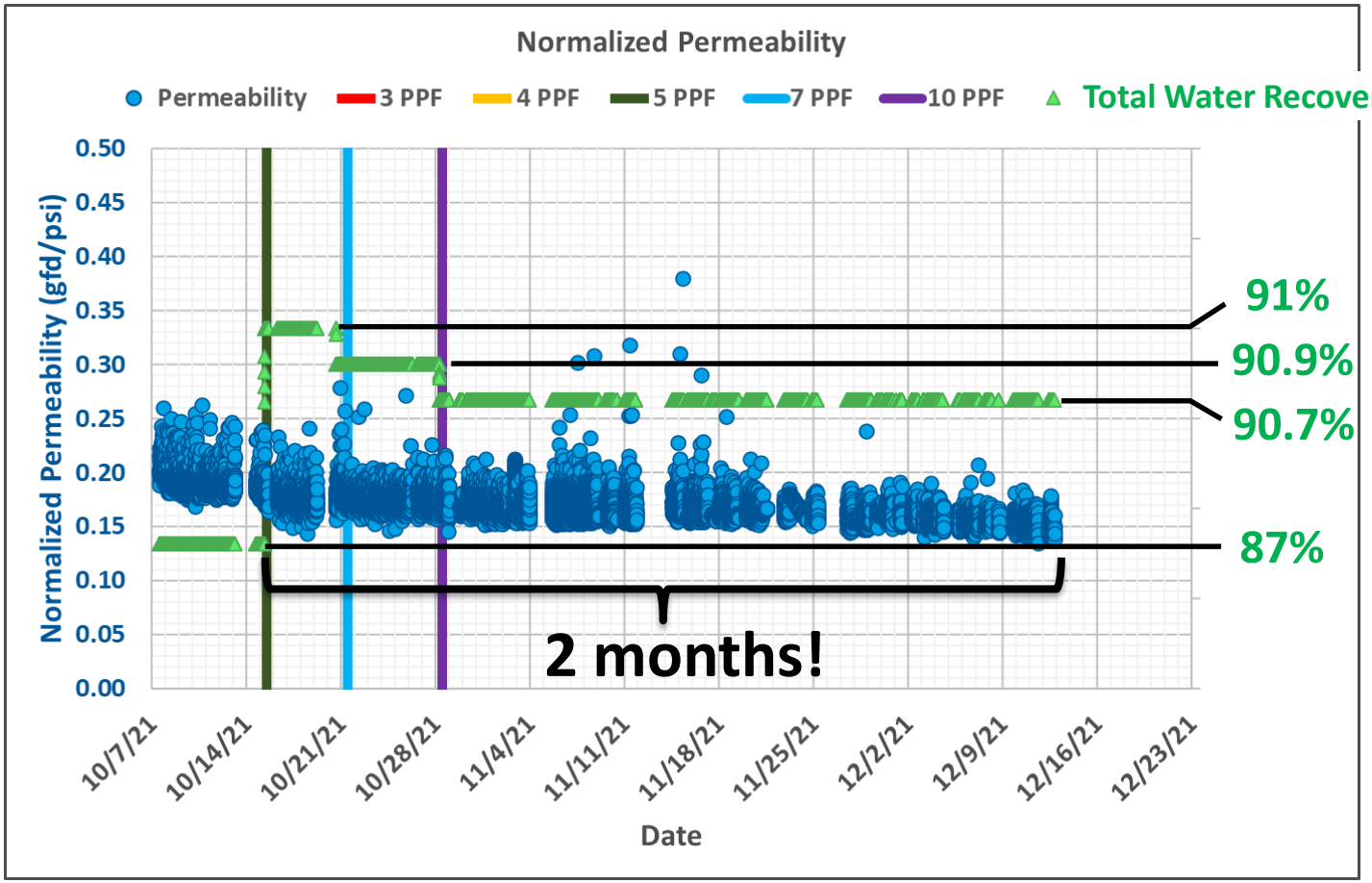
Periodically Lower Permeate Flush Frequency



Periodically Lower Permeate Flush Frequency



Periodically Lower Permeate Flush Frequency



Conclusions

SUCCESSES

- Over 24 months of pilot challenge testing data collected
- Stable short-term and long-term operation demonstrated at >90% total recovery using ReFlex™ MAX and optimized operations

LESSONS LEARNED

- CCRO feed pretreatment increases recovery
  - ✓ Control of calcium carbonate scale with feed acidification
  - ✓ Control of silica and sulfate scales using Vitec 7400

- Use of low-salinity flushing increases recovery for brine treatment
  - ✓ Control of scale formation using CCRO permeate as feed flush

- Desalitech **ReFlex™ MAX** system provides benefits over **ReFlex™**
  - ✓ Equipment and hydraulics provide flexibility

NEXT STEPS

- Phase 2
  - Continue extended duration testing
  - Refine conceptual full-scale design criteria
  - Refine financial evaluations

- Position for preliminary design of full-scale high recovery

Contact Information

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